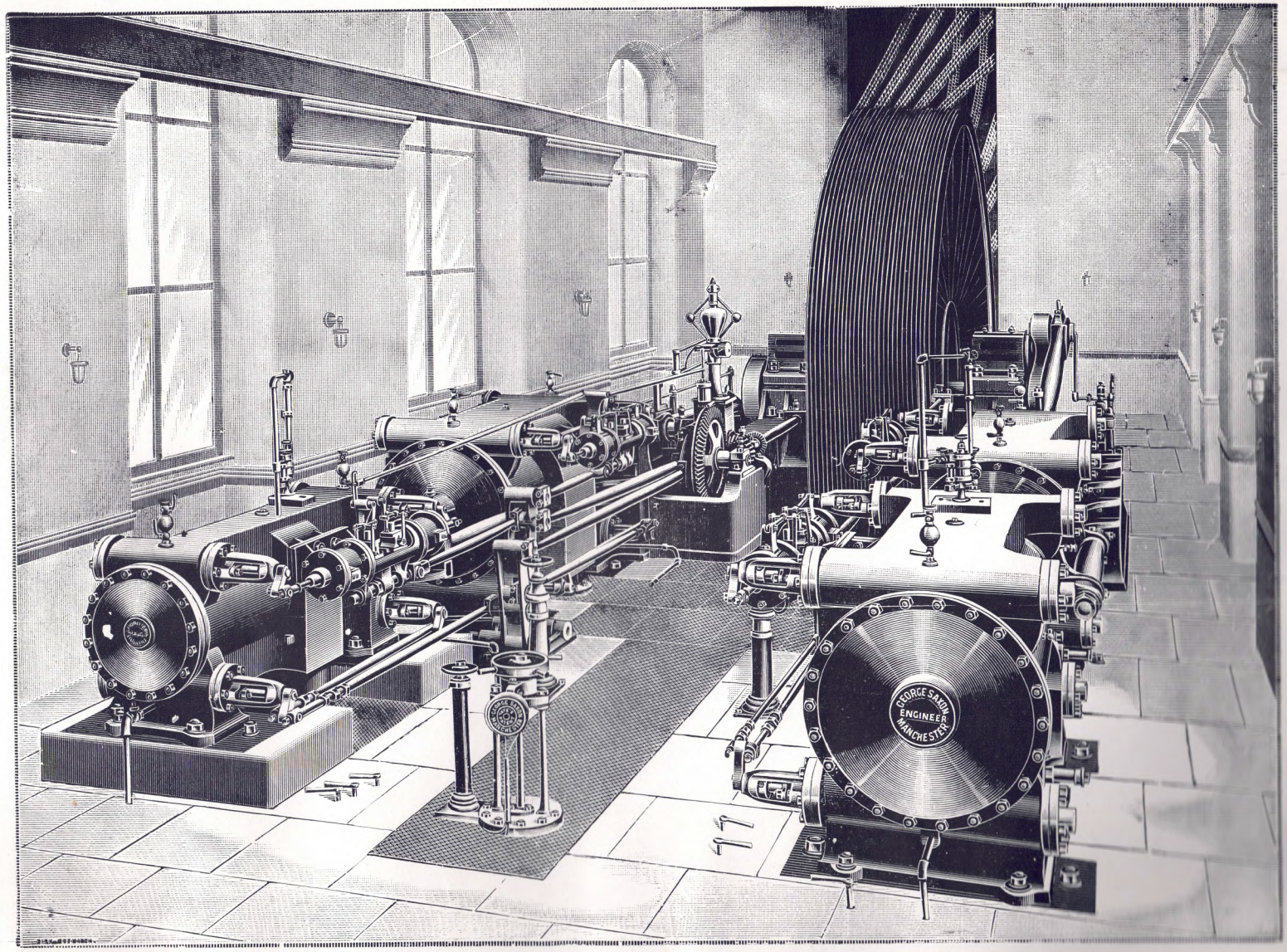
MACHINE DRAWING

BOOK 3.

T. JONES T. G. JONES



SET OF TRIPLE EXPANSION ENGINES ON THE FOUR CYLINDER PRINCIPLE,
FITTED WITH CORLISS VALVE GEAR,
CONSTRUCTED BY GEORGE SAXON, OPENSHAW ENGINEERING WORKS, MANCHESTER.

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MACHINE DRAWING

FOR THE USE OF

ENGINEERING STUDENTS

IN

SCIENCE AND TECHNICAL SCHOOLS AND COLLEGES

BY THE LATE

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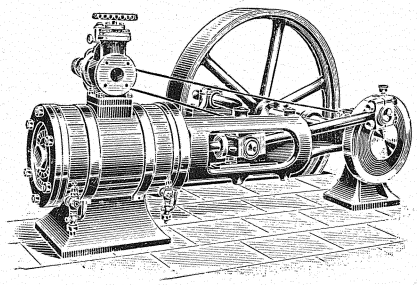

BOOK III.

ENGINE AND PUMP DETAILS.

NEW EDITION.

JOHN HEYWOOD LTD.

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PREFACE.

THE drawings of engine and pump details contained in this book will, we trust, appeal to all those students of engineering who take an interest in the construction and working of these important pieces of mechanism.

The whole of the examples are taken from actual engines and pumps as constructed at the present time by specialists in their particular line.

As far as possible, in the limited space at our disposal, a full description of the detail and its position and use in the complete machine is given, in direct connection with the drawing.

The side and end elevations are projected from each other, as explained in Book I.—the object is *in all cases* supposed to be placed between the eye of the spectator and the plane upon which it is projected. All engineers agree in doing this where a *plan* is projected from an elevation, then why not be consistent, and project one elevation from another in the same way?

The list of exercises given will assist the teacher in the selection of work suitable to the ability of the student. The teacher, or the student himself, may, however, select other examples as exercises; but in doing this, care should be taken to draw the details to as large a scale as possible. The advanced student should not be satisfied with drawing only those examples selected for him, but should draw many of the more elementary details, and at least study the whole of the mechanism in connection with the example he wishes to draw.

The various engineers who have so kindly helped us, by the loan of drawings, to prepare this series of plates, deserve the thanks of every student who wishes to gain special knowledge in this branch of engineering construction.

Our thanks are hereby given to the following engineers for their generous help:—Messrs. Alley and MacLellan, Glasgow; J. A. F. Aspinall, Esq., M.I.C.E.; Messrs. Beyer, Peacock and Co. Limited, Manchester; Messrs. W. H. Bailey and Co. Limited, Salford; Messrs. Campbell and Calderwood, Paisley; The Edwards' Air Pump Syndicate Limited, London; Messrs. Fielding and Platt Limited, Gloucester; Messrs. Gresham and Craven Limited, Manchester; Messrs. Holden and Brooke Limited, Manchester; Messrs. Mather and Platt Limited, Manchester; Robt. Middleton, Esq., Leeds; Messrs. Frank Pearn and Co. Limited, Manchester; Messrs. Ruston, Proctor and Co. Limited, Lincoln; Messrs. Reavell and Co., Limited, Ipswich; Hurry Riches, Esq., M.I.C.E.; Messrs. Ransomes, Sims, and Jefferies Limited, Ipswich; Messrs. Ernest Scott and Mountain Limited, Newcastle-on-Tyne; George Saxon, Esq., Manchester; Messrs. Steven and Struthers, Glasgow; The Editor of "*Engineering*"; The United States Metallic Packing Co., Bradford.

THOMAS JONES,
T. GILBERT JONES

MANCHESTER,
September, 1912.

PREFACE TO NEW EDITION.

IN this new edition many minor errors have been corrected, but no attempt has been made to introduce new subject matter.

January, 1920.

T. J.—T. G. J.

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Plate I.—JOY'S VALVE GEAR.

GENERAL ARRANGEMENT. Joy's valve gear is the most popular of the several radial valve gears, and is somewhat largely used on the locomotive engines of Great Britain to replace the type of valve gear known as Stephenson's Link Motion. It aims at the removal of the defects in steam distribution of the latter gear.

By a simple arrangement of links one end of the valve rod is constrained to move in an oval path, and, by varying the direction of this oval, the travel of the slide valve and the cut-off in the cylinder are varied, as well as, in some cases, the direction of running of the engine.

Since descriptions of the several links are given on the following pages, it is here only necessary to study the kinematics or geometry of the gear. On reference to the general drawing on Plate I., and the accompanying diagram,

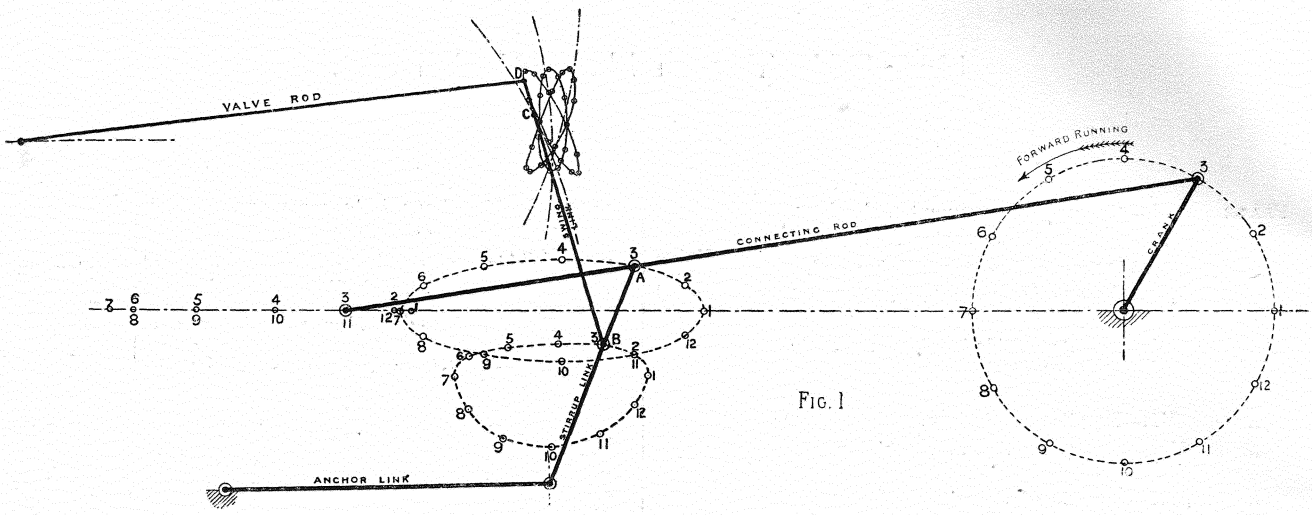


FIG. 1

the arrangement of the links may be understood. To some point **A** on the connecting rod is fixed one end of the stirrup link, whose lower end is attached to that end of the anchor link which is capable of moving about a fixed point of the slide bar bracket. The swing link is attached at one end to the point **B** of the stirrup link, while the point **C**, near the other end, is constrained to move in a circular path of radius equal to the length of the valve rod. The valve rod is connected with the end **D** of this rod.

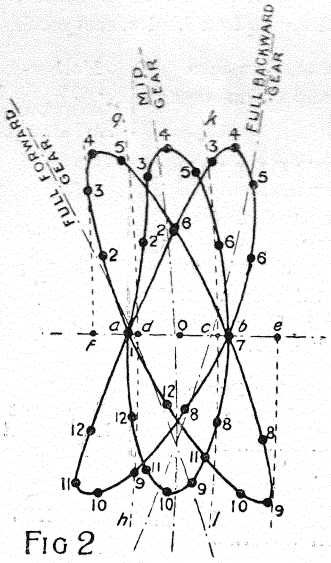


FIG 2

Since one end of the connecting rod moves in a straight line and the other in a circular path, the point **A** on the rod will have an approximately elliptical path. This motion of the point **A**, together with the circular motion of the lower end of the stirrup link gives to the point B the lop-sided path indicated in the diagram. The circular motion of the point **C**, together with the motion of the point **B**, derived from the stirrup link, constrains the point **D** to move along an oval curve, whose direction of length is approximately parallel to the direction of the curved guide for the point **C**. With the curved guide in the vertical position, *i.e.*, the position of *mid gear*, the horizontal width $a\,b$ (Fig. 2) of the curve would be the travel of the slide valve, and therefore equal to 2 (steam lap + lead); $o\,c = o\,d = 1''$ = steam lap, and $c\,b = d\,a = \frac{3}{16}''$ bare = lead.

For any other position of the curve guide—say *full forward gear*—the length $e\,f$ of the projection of the curve on the direction of motion of the valve is equal to the travel of the valve. Evidently, **the greater the angle which the guide makes with its mid position the greater will be the travel of the valve, and the later the cut-off.**

In order that the ovals described by the point **D** for all positions of the guide may intersect in the two common points a, b—and so make the lead constant for all steam distributions—the fulcrum pin of the swing link must coincide with the centre of oscillation of the guide when the crank is on either dead centre. Then, for this

[*Continued on next page.*

EXERCISES.

*1. **General Arrangement of Valve Gear.** Draw the side elevation and plan as given. *Scale* $1\frac{1}{2}'' = 1$ *foot.* If the drawing be made on a sheet of imperial size, add an end elevation looking from the cylinder towards the crank axle, and draw to a *scale* $\frac{1}{6}$ *full size.*

*2. Draw a line diagram of the gear as shown in Fig. 1, and determine the paths described by the points **A, B, C, D,** on the links, when the curved guides are: (*a*) in mid gear; (*b*) full forward gear; (*c*) full backward gear; and for positions (*b*) and (*c*) determine the point of cut-off in the cylinder.

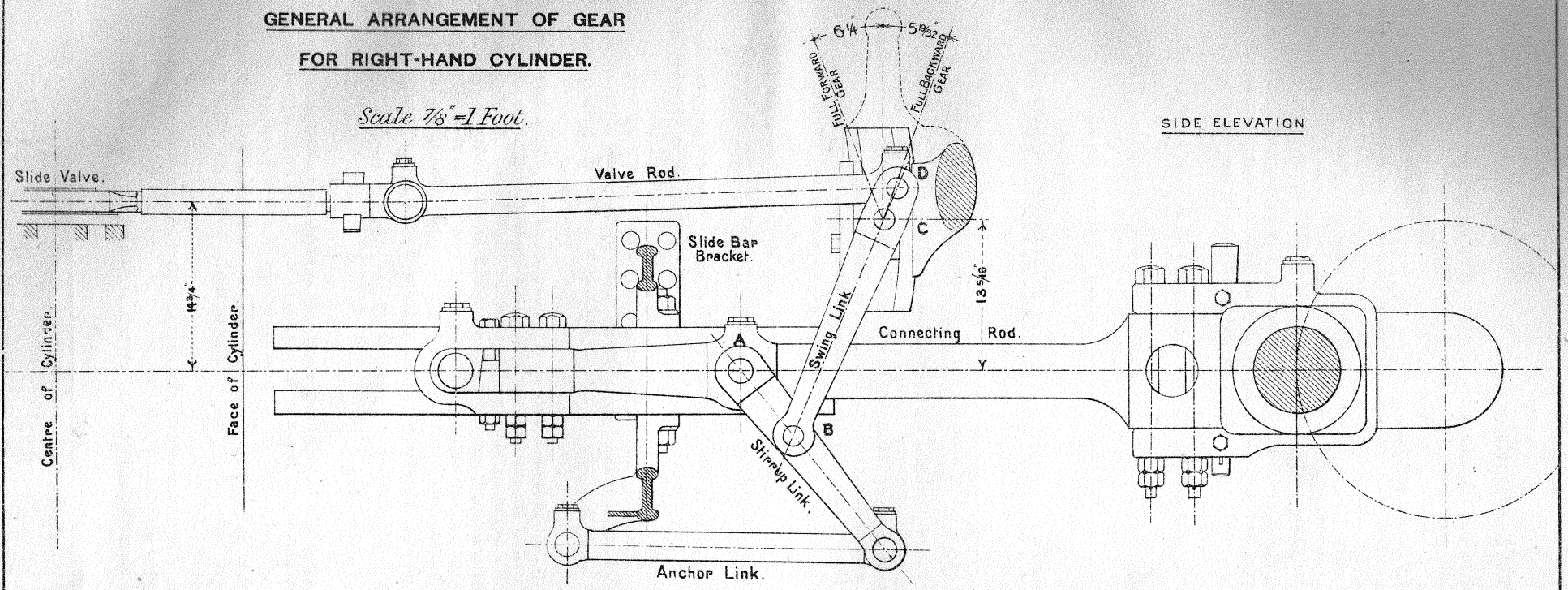
N.B.—On no account should the above Exercises be attempted until all, or at least the more difficult details have been drawn separately.

* Exercises suitable for Second and Third Year or Advanced Students are, throughout the book, marked with an asterisk (*).

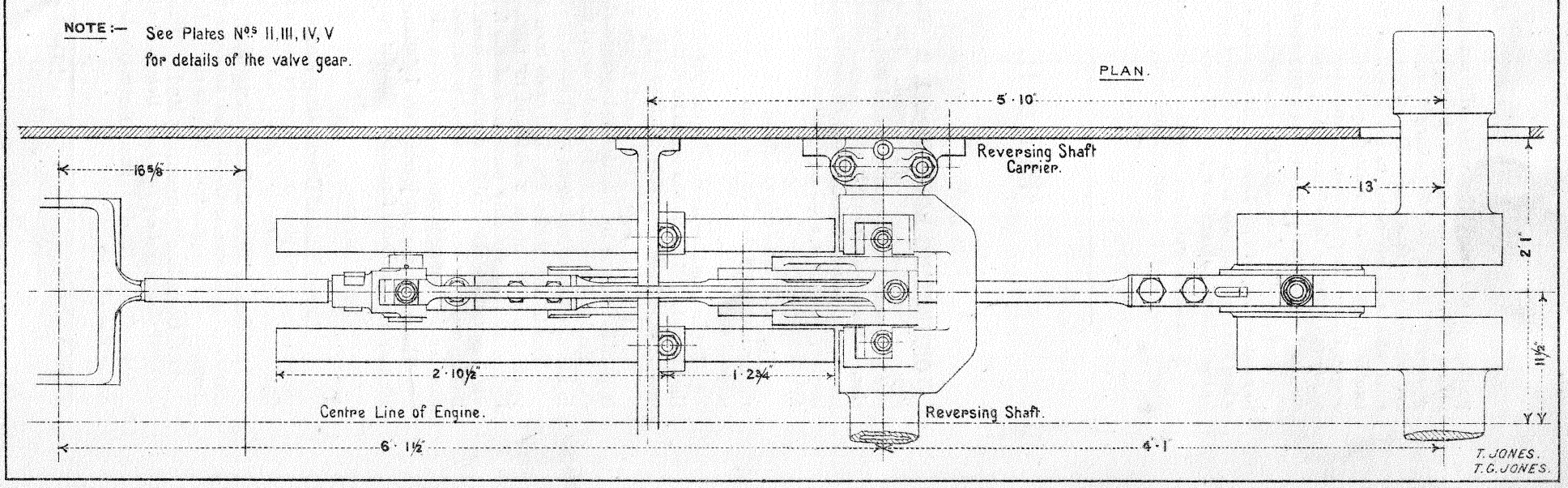
JOY'S VALVE GEAR FOR LOCOMOTIVE (L. & Y. RAILWAY).

GENERAL ARRANGEMENT OF GEAR FOR RIGHT-HAND CYLINDER.

Scale 7/8" = 1 Foot.



NOTE:— See Plates Nos II, III, IV, V for details of the valve gear.



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position of the crank the valve will not move when the reversing arm is moved from one extreme position to the other. The curves described by the point **D** for the three positions—*full forward*, *mid*, and *full backward gear*—are drawn to an enlarged scale in Fig 2, and the positions of **D** given for the twelve equidistant positions of the crank pin. The curves *g d h* and *k c l* are drawn from points on the centre line of the valve spindle, each with a radius equal to the length of the valve rod. Hence, when the point **D** is in any position outside these two lines, one or other steam port will be open by an amount equal to the distance of the point from the *nearer* line The horizontal projection of the curve between two consecutive points is equal to the motion of the valve during the corresponding displacement of the crank, and so it may be noticed that the valve opens and closes each steam port promptly, and has a very slow motion when the port is fully open.

Starting with the point **D** in the position *a*, and the crank on the *out* dead centre, it is evident that if the shaft is to rotate in the forward direction, the right-hand steam port must open and the point **D** move along a curve described when the reversing arm is in some forward position, *i.e.*, to the left of the mid position, otherwise the valve would move to the right and close the right-hand port.

NOTE.—The cylinders have an inclination downwards towards the crank shaft of 1 in 10, but for convenience in drawing they may be assumed horizontal.

Plate II.—JOY'S VALVE GEAR.

CONNECTING ROD, Figs. 1, 2. The rod is of steel and has an effective length of $6' - 2''$, being about 5·7 times the length of the crank. The brasses of the large end are lined with spiral strips of white metal, and are secured to the rod by a steel strap and two steel taper bolts, the latter fitted with double nuts and taper split pins. Their adjustment is effected by means of a steel block and a cotter, the latter being fixed by two $\frac{5}{8}''$ set screws, and a key fitting across its small end. On the top side of the strap, immediately above the centre of the bearing, there is a square projection which is bored out to form an oil cup. The rod end is lightened by a hole $4\frac{1}{2}''$ diameter.

The brasses for the crosshead end are without flanges, and are secured by a steel strap and two taper bolts in a similar manner to those at the crank pin end, but are adjusted by a steel wedge which is moved by means of a steel bolt screwed through it.

The intermediate bearing for the pin of the stirrup link is fitted with a phosphor-bronze bush riveted over flush at the two ends. Between the big end and the middle bearing the rod is of uniform section $4\frac{3}{4}'' \times 1\frac{3}{4}''$, but from the middle bearing to the small end it tapers from $4\frac{3}{4}'' \times 1\frac{3}{4}''$ to $3\frac{1}{2}'' \times 1\frac{3}{4}''$.

The three oil cups, Figs. 3 and 4, are alike. The filling hole in the brass cap is closed by a brass button, which is held in position by a light coiled spring and guided in its motion, when pressed down by the spout of the oil can, by the tube formed with it fitting loosely round the oil hole. A slot in the tube of the button enables the trimming to hang in the oil reservoir and down the oil hole.

The Crank Axle, Fig. 5, is made from an ingot of Siemens-Martin steel, hammered down under a very powerful hammer to a slab about 2′ wide and 12″ thick. Portions are cut from one side at the two ends and in the centre of its length, so that the only parts now of the full width are those which are to form the crank arms. After the portions which go to form the straight shaft have been hammered round, and the forging reheated in the middle, the slab for the leading crank, or the leading *sweep*, is twisted through a right angle. When the *sweeps* have been rounded under the hammer the forging is ready for the lathe. It will be seen that the crank arms taper in width from the pin to the shaft.

The crank pins and journals are $7\frac{1}{2}''$ diameter, and the wheel seats, $8\frac{5}{8}''$ diameter $\times$ $7\frac{3}{16}''$ long. After the key-ways are cut, the wheels are forced by hydraulic pressure on to the shaft and then keyed.

EXERCISES.

1. **Large End of Connecting Rod.** Draw the side and sectional elevations as given, also a complete plan and a complete sectional plan (not one figure showing half plan and half sectional plan as in Fig. 1), and add an end elevation looking towards the right. *Scale* $\frac{1}{2}$ *full size.* Draw the details of the oil cups separately to a *scale* $\frac{3}{4}$ *full size.*

2. **Small End of Connecting Rod.** Draw the following complete views:—Side elevation, sectional side elevation, plan and sectional plan and add two end elevations. (Project the sectional plan from the sectional side elevation, and the plan from the side elevation.) *Scale* $\frac{1}{2}$ *full size.*

*3. **Complete Connecting Rod.** Draw the side and sectional elevations as given, also a complete plan and a sectional plan. *Scale* $\frac{1}{3}$ *full size.* Details of oil cups to be drawn $\frac{1}{2}$ *full size.*

4. **Crank Shaft.** Draw the complete side elevation and the end elevation given in Fig. 5, and add a plan. *Scale* $2'' = 1$ *foot.*

---

* This Exercise is intended for Advanced Students.

JOY'S VALVE GEAR FOR LOCOMOTIVE (L. & Y. Railway).

DETAILS OF CONNECTING ROD.

Scale 2"=1 Foot.

SIDE AND SECTIONAL ELEVATIONS.

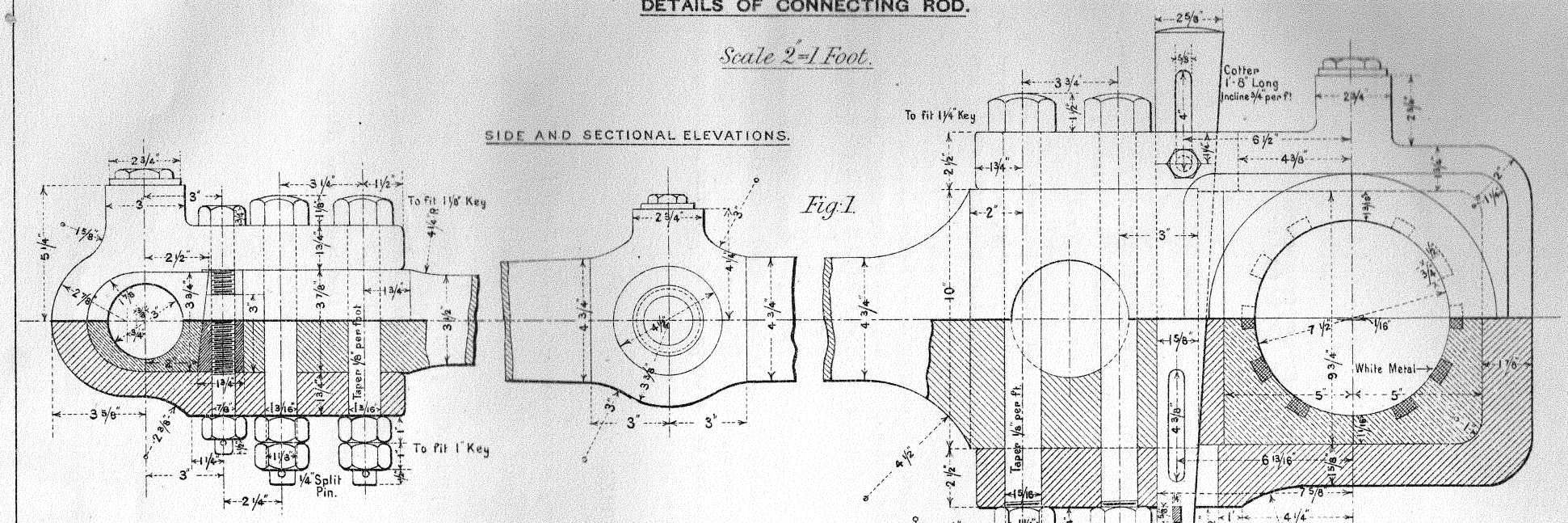

Fig. 1.

PLAN AND SECTIONAL PLAN.

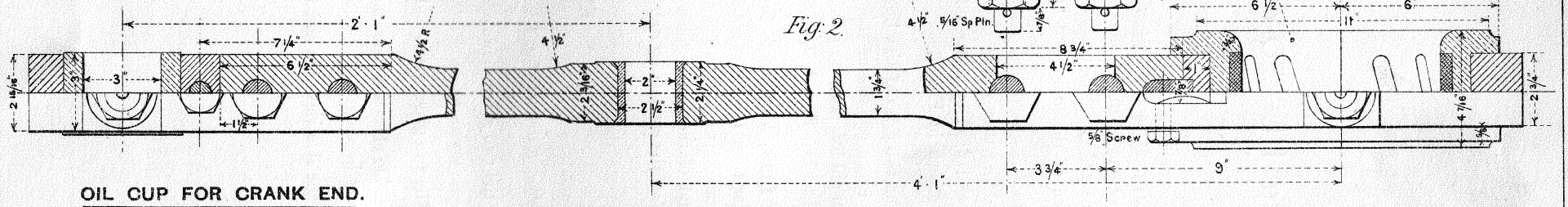

Fig. 2.

OIL CUP FOR CRANK END.

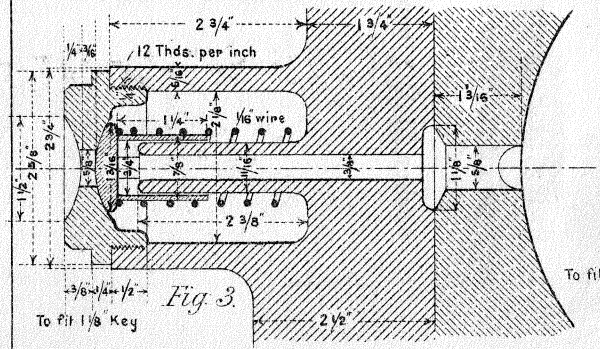

Fig. 3.

Scale ⅜ full size.

OIL CUP FOR MIDDLE BEARING.

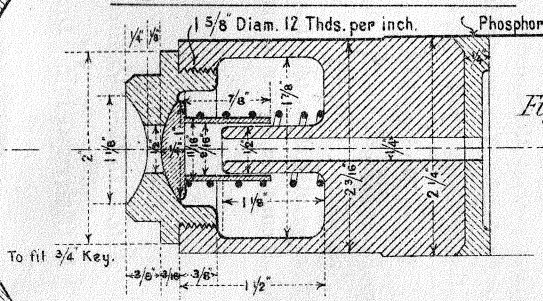

Fig. 4.

Scale 6"=1 Foot.

CRANK SHAFT.

Scale ½"=1 Foot.

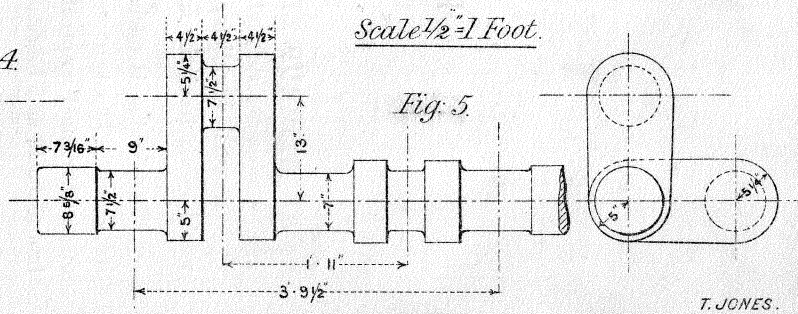

Fig. 5.

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Plate III.—JOY'S VALVE GEAR.

THE STIRRUP LINK, Fig. 1, is the link whose ends are connected with the intermediate bearing of the connecting rod and the free end of the anchor link respectively. It is introduced into the gear to correct the unequal vibration of the centre C of the swing link, above and below the centre of the reversing shaft, which would result from the connection of the lower end of the swing link with the connecting rod.

The forging is made in two straight pieces, each with enlarged ends and a thickened part near the centre of its length. The two are welded together where the bearing for the swing link is to be situated. The pins are of case-hardened wrought iron, and fixed by taper split pins. The intermediate bearing is fitted with a phosphor-bronze bush, and lubricated as shown in Fig. 2.

Swing Link, Fig. 3. The two sides of the link are worked from wrought-iron forgings, and are held parallel by the pins at the ends. The lower pin fits in the bearing of the stirrup link, and the top end is attached to the valve rod end. The intermediate pin has prolonged ends to carry the bronze blocks which move in the curved guides of the reversing shaft. (See Plate IV., Figs 1, 2, 3, 6.)

Valve Rod and Anchor Link, Figs. 4, 5, 6. These two rods are of the same design, and are made from wrought-iron bars, slightly thicker than the rod ends. The middle of each is drawn down under the steam hammer to give, when machined, the rectangular section $2\frac{1}{2}'' \times 1''$. The two ends of the anchor link and one end of the valve rod are exactly alike, but that end of the latter which is attached to the top pin of the swing link is widened to $3\frac{1}{2}''$. The oil cups are similar to those on the connecting rod.

EXERCISES.

Note.—To the scales given below, Exercises Nos. 1 and 2 may be drawn together, and Nos. 3 and 4 together.

1. **Stirrup Link.** Draw the two given views and add a plan. *Scale $\frac{3}{8}$ full size.* Draw the details of the oil cup *full size.*

2. **Swing Link.** Draw the two given views and add a plan. *Scale $\frac{3}{8}$ full size.*

3. **Valve Rod.** Draw the side elevation (one end in section), the plan and two end elevations. *Scale $\frac{3}{8}$ full size.* The full length of the rod need not be shown.

4. **Anchor Link.** Draw the side elevation and the plan. *Scale $\frac{3}{8}$ full size.* Details of oil cup, *full size*

JOY'S VALVE GEAR FOR LOCOMOTIVE (L. & Y. RAILWAY).

DETAILS OF LINKS AND VALVE ROD.

STIRRUP LINK

Scale ⅕ full size.

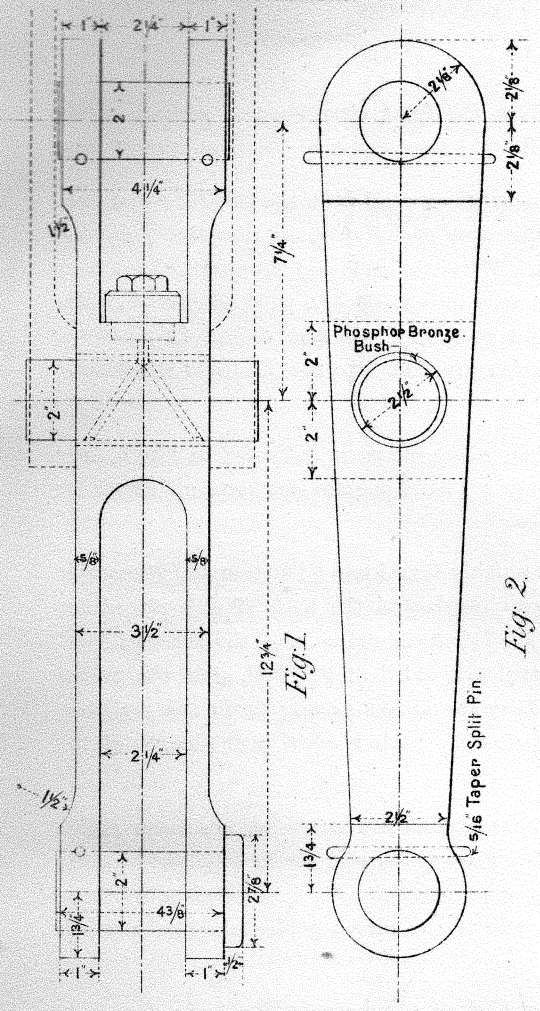


Fig. 1.

OIL CUP FOR STIRRUP LINK.

Scale ½ full size.

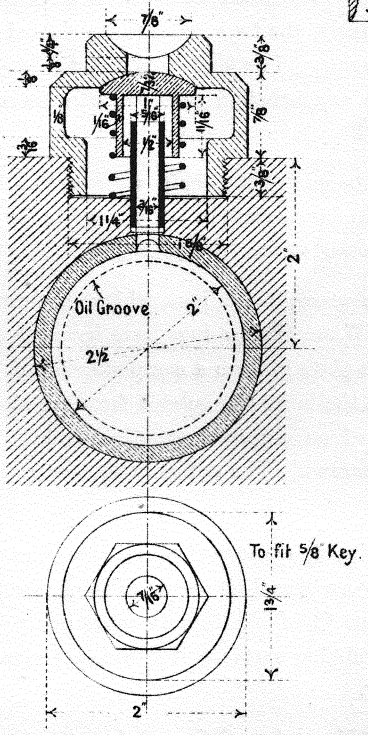


Fig. 2.

SWING LINK.

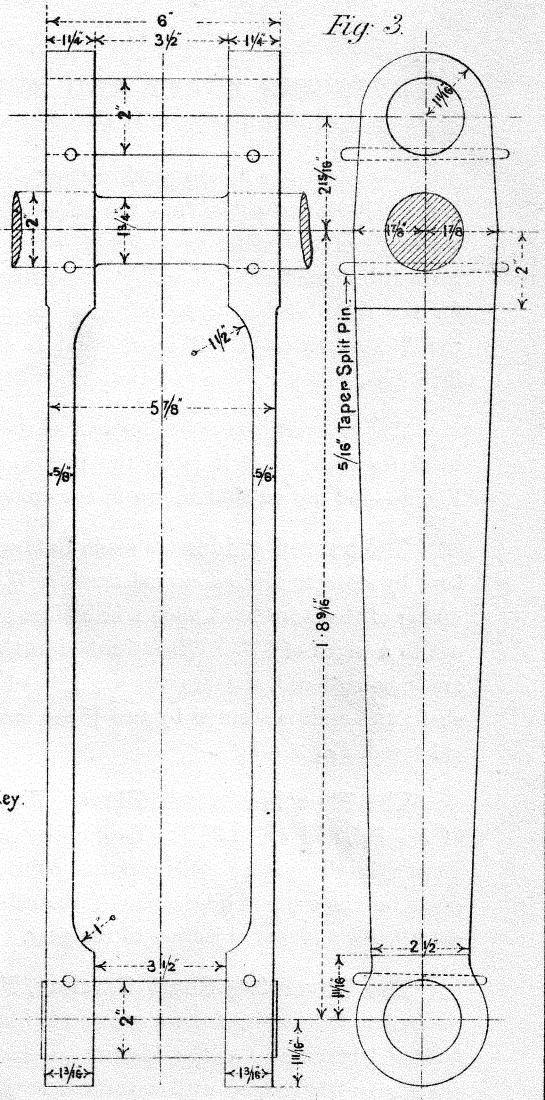


Fig. 3.

VALVE ROD.

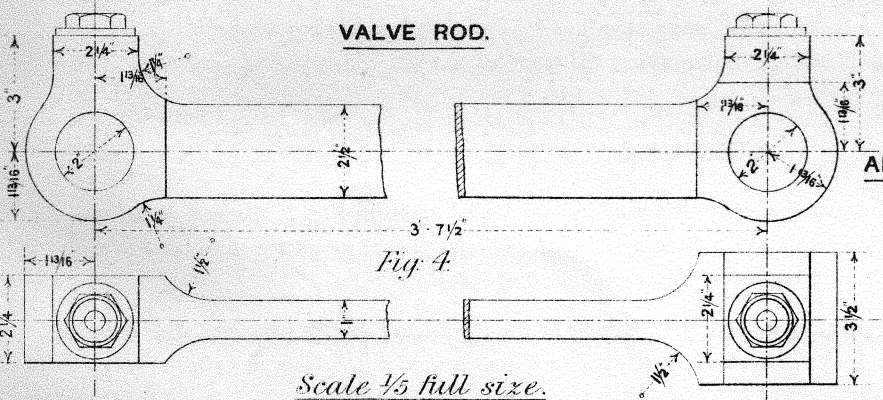
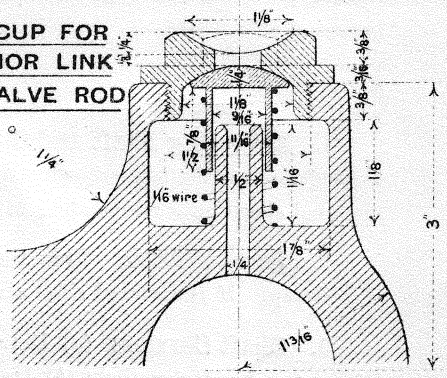


Fig. 4.

Scale ⅕ full size.

OIL CUP FOR ANCHOR LINK AND VALVE ROD



ANCHOR LINK.

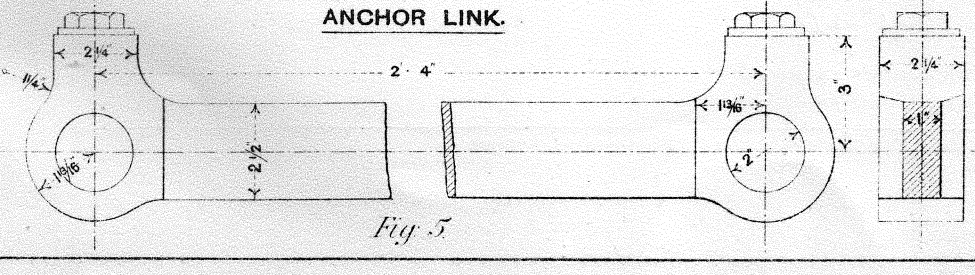


Fig. 5.

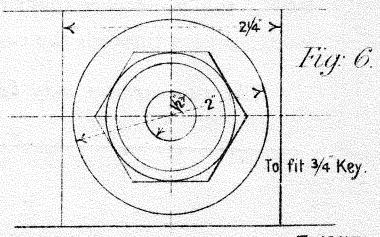


Fig. 6.

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Plate IV.—JOY'S VALVE GEAR.

REVERSING SHAFT AND GUIDES. In Figs. 1, 2, 3, are given the front elevation and section—when viewed from the cylinder end of the engine—the plan of half the shaft and a cross sectional elevation respectively.

The shaft is a hollow steel casting which has been thoroughly annealed by its removal from the mould whilst hot, and by its introduction into the annealing furnace. Afterwards it is allowed to cool slowly, so that the molecular structure of the metal may not give rise to any undue internal stresses. When the ends and the middle have been turned to diameters of 5″ and 6″ respectively, the four recesses are slotted out to receive the two pairs of curved guides for the right-hand and the left-hand engine. The shaft has a total length of $4' - 1\frac{7}{8}''$, so that it just fits between the engine frames—$4' - 2''$ apart—and is supported in cast-iron carriers which are bolted to the insides of the frames. (See Figs. 4, 5.)

The wrought-iron reversing arm at the end of the shaft is bolted to a lug, whose shape is indicated in Fig. 3, only in *dotted lines*, since it is on the part which carries the outside guide for the left-hand engine—see sectional elevation, Fig. 1—and not on that shown in the cross section.

The curved guides are made from wrought-iron bars, which are first roughly forged to a ⌊ section and afterwards bent by stamping into a curved recess. When the forgings have been sawn to length, and the back of each planed up, fifteen of them are fixed upon a lathe face-plate to form a complete ring of $3' - 7\frac{1}{2}''$ mean radius, and the recess turned out to a width of $3\frac{1}{4}''$. When finished in the lathe the outside faces are slotted to a width of $5\frac{1}{4}''$, and, after the guides are case-hardened, the grooves are ground on a special grinding table. They are made a driving fit in the reversing shaft, and each is secured by two $\frac{3}{4}''$ set screws. The radius of the centre line of the guide is equal to the length of the valve rod, *i.e.*, $3' - 7\frac{1}{2}''$.

The Phosphor-bronze Blocks, Fig. 6, are turned up on the lathe face-plate, sixteen at a time, to a mean radius of $3' - 7\frac{1}{2}''$, and width $3\frac{1}{4}''$. Two blocks are placed on the ends of the intermediate pin of each swing link, and by their motion in the guides constrain the point **C** of the link to move in the required curved path. Although provision is made for the copious lubrication of the rubbing surfaces, it is the excessive wear of the curved guides and blocks which constitutes a severe objection to the gear.

The Reversing Shaft Carriers, Figs. 4 and 5, are of cast iron, and of simple design The body of each is secured to the inside of the engine steel frame by four 1″ bolts, and the cap held down by two 1″ bolts. The cap of the left-hand bearing—*i.e.*, the bearing on the left-hand side, when standing in the cab and looking towards the front of the engine—is formed with a vertical ridge 1″ wide, running along the front edge upon which the bottom edge of the reversing arm moves.

EXERCISES.

*1. **Reversing Shaft and Guides.** Draw the front elevation and section as given in Fig. 1, the end elevation—looking towards the left—showing the reversing arm, the half plan and half sectional plan through the axis, and a cross sectional elevation corresponding with Fig. 3 to the right of the sectional plan. *Scale* 3″ = 1 *foot.*

2. **Bronze Block.** Draw the three given views of Fig. 6, adding in the right-hand section the cap and valve of the oil cup. If the curved sides cannot be drawn conveniently, they may be made straight. *Scale full size.*

3. **Shaft Carriers.** (*a*) Draw the three views of Fig. 4, and add a sectional side elevation, through the axis, to the left of the front elevation: (*b*) Draw and complete the two views of the left-hand carrier, given in Fig. 5, and add a sectional plan through the centre. *Scale* 4″ = 1 *foot.*

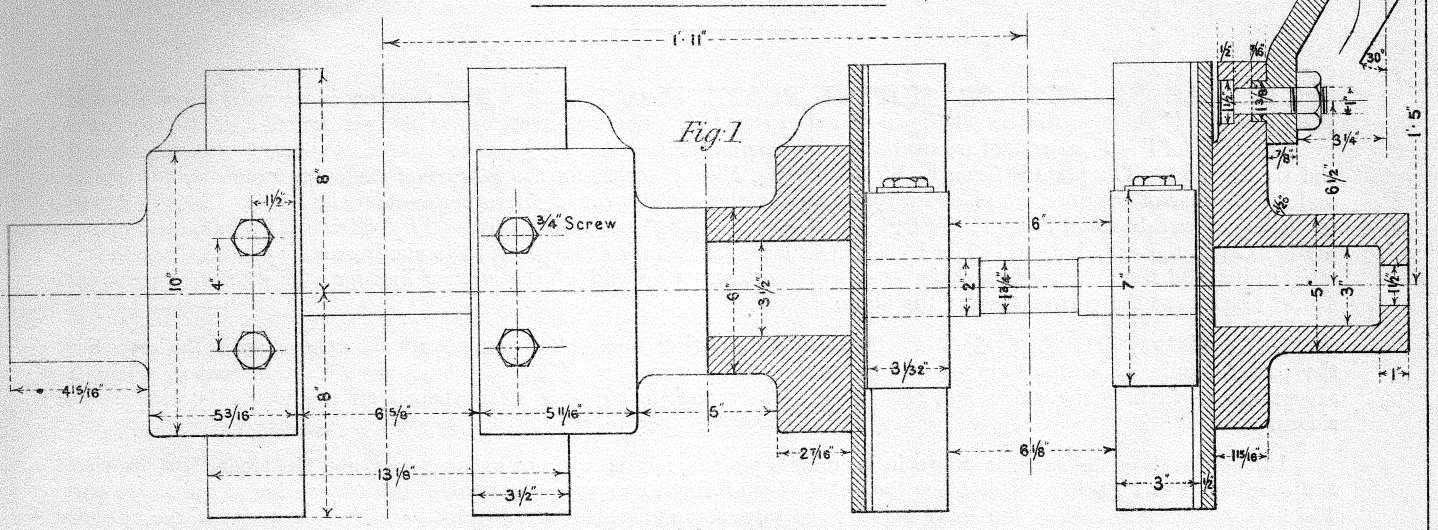
The two carriers may be drawn together on one sheet of paper.

* This Exercise is intended for Advanced Students.

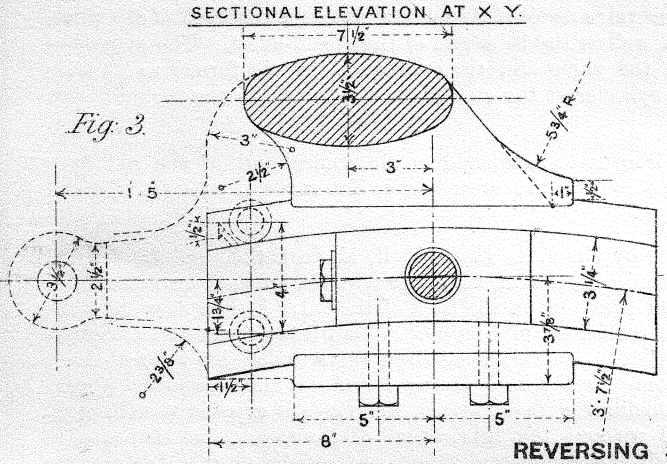
JOY'S VALVE GEAR FOR LOCOMOTIVE (L. & Y. RAILWAY.)

REVERSING SHAFT AND SLIDES.

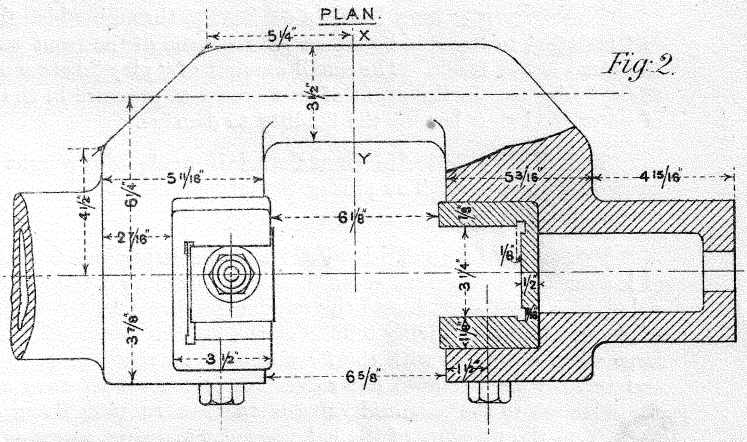
FRONT ELEVATION AND SECTION



SECTIONAL ELEVATION AT X Y.

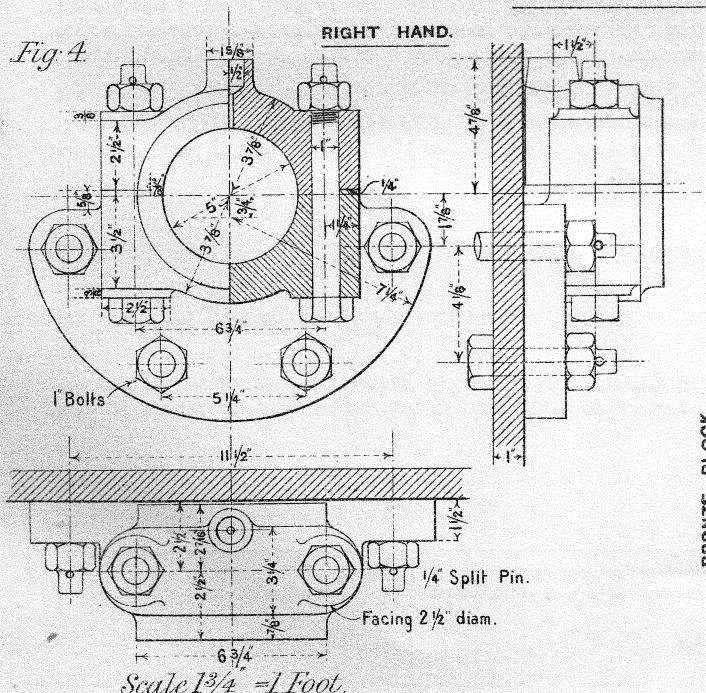


PLAN.



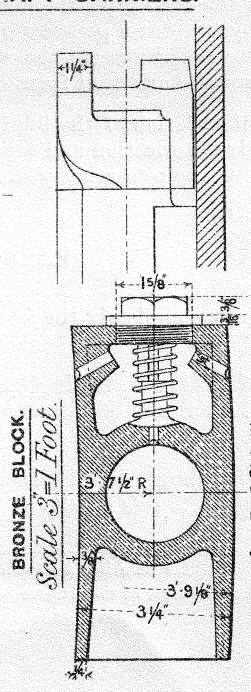
REVERSING SHAFT CARRIERS.

RIGHT HAND.



Scale 1 3/4" = 1 Foot.

BRONZE BLOCK.
Scale 3" = 1 Foot.



See Fig 6, Plate III. for further details of Oil Cap etc.

LEFT HAND.

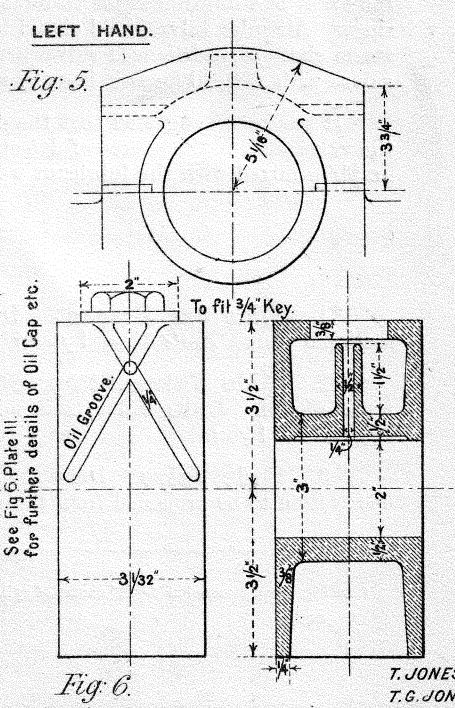


Fig. 6.

T. JONES.
T.G. JONES

Plate V.—JOY'S VALVE GEAR.

SLIDE-BAR BRACKET OR MOTION PLATE, Figs. 1, 2, 3. The bracket is a well annealed steel casting, $\frac{7}{8}''$ thick, with the edges thickened up to $1\frac{7}{8}''$. The two rectangular flanges are planed to the exact distance of $4' - 2''$ apart, and are secured to the engine frame plates by $\frac{7}{8}''$ turned rivets, countersunk on the outside, and riveted cold. The plate is formed with two holes, $1' - 11''$ apart, for the passage of the connecting rods through it, and at the sides of each one are planed projections for the attachment of the crucible-steel slide bars. As will be seen from the general drawing, Plate I., the bars are $4' - 1\frac{1}{4}''$ long, $3\frac{1}{2}''$ apart vertically, and $6\frac{1}{2}''$ horizontally. One end of each bar is fixed to the cylinder end. The $1''$ bolts, securing the bars to the plate, have countersunk cylindrical heads with steady pins, and the nuts are locked by steel split cotters. One end of the anchor link for each gear is attached to a forked bracket, at the bottom edge of the plate.

Slide Valve, &c., Figs. 4, 5, 6. The valve is a casting of phosphor bronze, and the care taken in the moulding, the pattern and the composition of the metal remove the necessity of any machine work on the casting, with the exception of grinding the valve face and edges. The top of the valve is strengthened on the inside by two narrow ridges.

In the elevation the valve is shown in its middle position: it is without exhaust laps, and the steam laps are equal and each equal to $1''$, being the distance the outer edge of the valve projects beyond the outer edge of the steam port. The four $\frac{5}{16}''$ holes in each of the short edges of the valve serve to enable the lubricant to reach those parts of the cylinder face which are never uncovered by the valve in its travel.

The wrought-iron Buckle or Strap, through which the valve receives its motion, fits over the back of the valve, and is forged to the spindle which passes through the front as well as the back end of the steam chest. The outside of the strap is left black. The small amount of "play" between the valve and the buckle enables the former to lift from the cylinder face in the event of an increase of pressure in the cylinder at the end of the stroke due to the accumulation of water, and thus lessens the liability to damage.

The Valve Spindle Crosshead is made of wrought iron, and is attached to the conical end of the rod by a wrought-iron cotter. The pin for the attachment of the valve rod to the crosshead is also made of wrought iron and case-hardened.

Friction of the Slide Valve. The experiments made by Mr. J. A. F. Aspinall, M. Inst. C.E., on the friction of locomotive slide valves show that, with ordinary working pressure of steam, the force required to work an unbalanced valve, like the above, due to the friction produced by the steam pressure on the back of the valve had an average value of about 2,000 lbs, giving 0·0878 as the average value of the coefficient of friction. This frictional resistance appears large when compared with the force of 854 lbs. required to actuate a balanced cast-iron valve under similar conditions, and yet, neither balanced flat valves nor piston valves have come largely into favour for use in the locomotive engine. An objection to the balanced valve is that, in running down inclines without steam, the valve is exposed to additional work from the pressure of the balance springs being continual without the lubrication of the steam, and that also, in the event of a down draught through the blast pipe, the fine grit will cut the valve face, and rapidly destroy the packing rings. Air inlet valves, held closed by the steam pressure when the regulator is open, should always be provided on the steam chest when balanced valves are used to prevent the vacuum which would cause a down draught. The friction of valves with vertical faces is less than with horizontal faces.

It has been suggested that the dissociation of the lubricant due to the high pressure, and not the high pressure on the valve face, is the source of defective lubrication and excessive wear of the face of the slide valve and ports, and that graphite mixed with the lubricant would help to remedy the defect.

EXERCISES.

*1. **Slide Bar Bracket.** Draw completely the front elevation, the sectional elevation, the half plan and half sectional plan. *Scale* $3'' = 1$ *foot.*†

*2. **Slide Valve, Strap and Valve-Spindle Crosshead.** Draw the given elevation, complete the plan and cross section of the valve, and add an end elevation viewed towards the right and projected from the plan. *Scale* $4'' = 1$ *foot.*

3. **Slide Valve.** Draw the front and the side elevation, the front and the side sectional elevation and the plan, one section to be projected from the plan. *Scale* $\frac{1}{2}$ *full size.*

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* These Exercises are intended for Advanced Students.

† In Fig. 1 the dimension 1'· 11" centre of cylinders should be the distance between the centres of the forked brackets, and not as shown on the drawing.

JOY'S VALVE GEAR FOR LOCOMOTIVE (L. & Y. RAILWAY).

FRONT ELEVATION

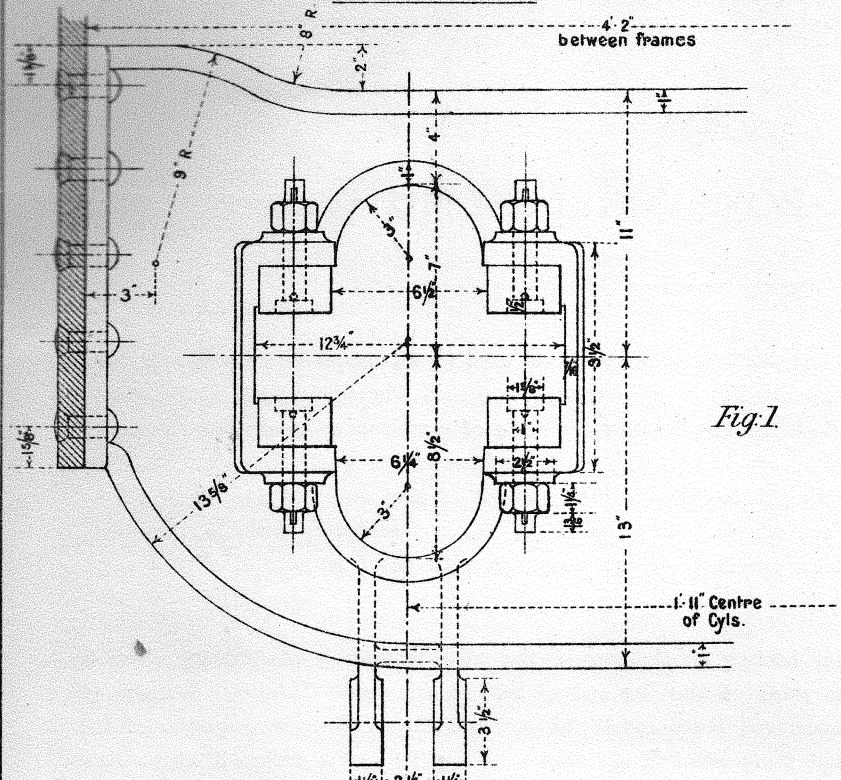


Fig. 1.

SECTIONAL ELEVATION

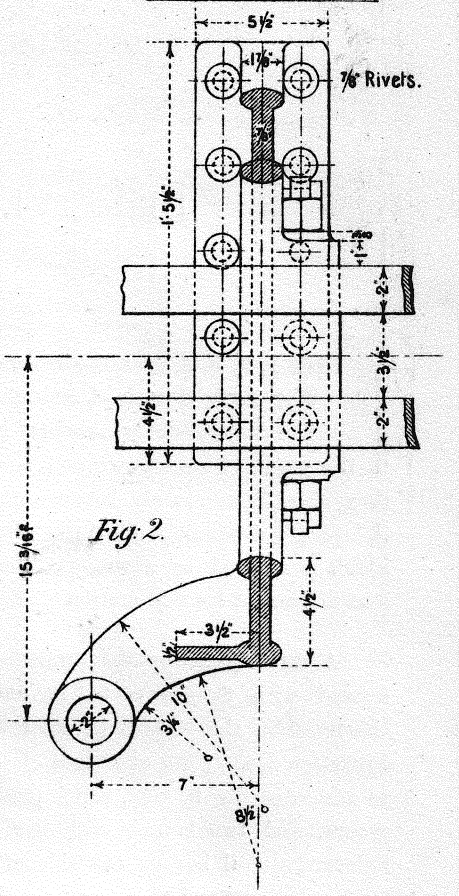


Fig. 2.

SECTIONAL PLAN.

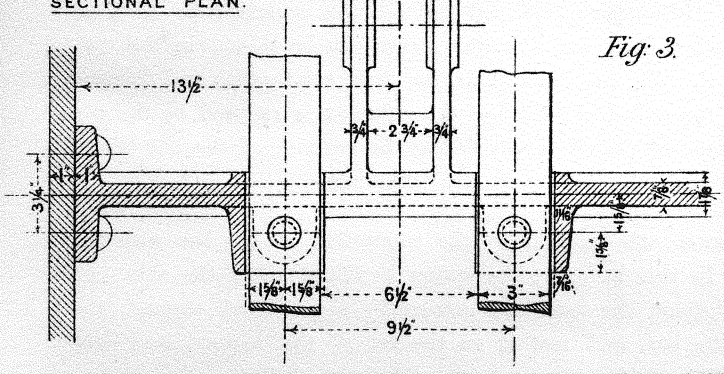


Fig. 3.

SLIDE BAR BRACKET.

Scale 1½" = 1 Foot.

SLIDE VALVE AND STRAP AND VALVE-SPINDLE CROSSHEAD.

Fig. 4.

ELEVATION

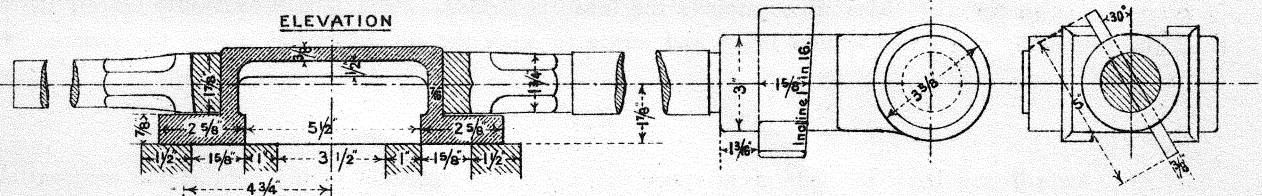
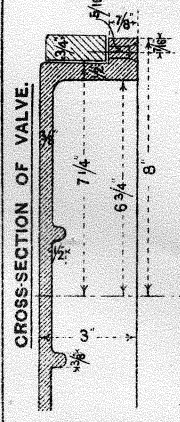
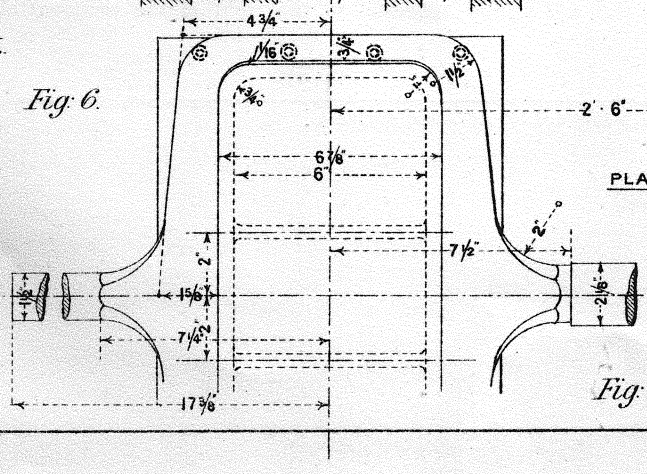


Fig. 6.

CROSS-SECTION OF VALVE.





Scale 2" = 1 Foot.

PLAN.

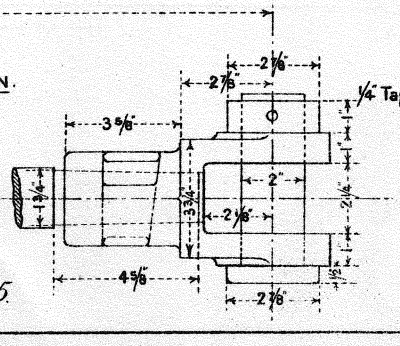


Fig. 5.

T. JONES.
T. G. JONES.

Plate VI.—AXLE-BOX FOR LOCOMOTIVE.

FIGS. 1, 2, 3, 4, give the several projections and sections of an axle-box used for an engine with inside cylinders. **The Axle-Box** is of wrought iron, of an inverted U form, with flanges on each side running the whole length. The horn-block or axle-box guide—not shown in the drawing—is made of cast iron or steel, and is secured to the engine frame by turned bolts, $1\frac{1}{8}''$ diameter, or rivets. The working faces of the guide are planed so that they may fit accurately between the flanges of the axle-box with a small amount of play on each side, varying from $\frac{1}{32}''$ to $\frac{1}{8}''$, depending upon the arrangement of the wheels. The top of the box is recessed to form a tallow cup, which is covered by a wrought-iron plate $\frac{1}{8}''$ thick provided on the underside with short lengths of curved angle iron to prevent its side motion.

Accurately fitting the inside of the box, and bearing on the top of the axle journal is the **brass**, which is formed with flanges to fit in recesses on the sides of the box and so hold it sideways. The brass is made $\frac{1}{8}''$ shorter than the journal in order to give clearance, and bears round the journal only over about a quarter of the circumference. (The clearance of the brass round the journal is not shown in Fig. 1.) It is designed with a view to minimise the friction, being provided with strips of white metal cast into recesses in the brass, and one main oil groove, and two branch ones inclined to its length at 45° on each side, fed through the central tube from an independent oil box on the side of the engine frame. Before these white metal strips can be shown in the two sectional elevations they must be drawn in the plan, Fig. 3, using the dimensions, for their axial width and distance apart, given in Fig. 2. The bearing area of the brass with the crown and sides of the axle-box is reduced by the top bevelled edges and the two recesses on each side. In the event of the oil supply failing the warming of the box would melt the tallow, and so it would be fed through the two inclined tubes by the woollen trimmings.

A portion of the weight of the engine is borne by each axle journal by the connection of the box with the bearing spring, which is slung from the engine frame. In this instance, the spring is placed below the axle, and connected with the box by a T headed hanger, bored through the head and carried by a pin fitted through the head and the sides of the axle-box. At the bottom of the box, and resting on the top of the hanger, is a light iron casting—called the **keep**—which contains a lubricating pad. Attached to a thin curved frame of steel is a piece of woollen material—from whose strands the brush is formed—which is pressed lightly against the underside of the journal by two coiled springs below, and serves to catch the oil and spread it over the surface.

EXERCISE.

*1. **Axle-Box.** Draw the four given views, and add a front elevation to the right of the sectional elevations. *Scale $\frac{3}{8}$ full size.*

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* This Exercise is intended for Advanced Students.

AXLE-BOX FOR LOCOMOTIVE.

SECTIONAL ELEVATION AT C. D.

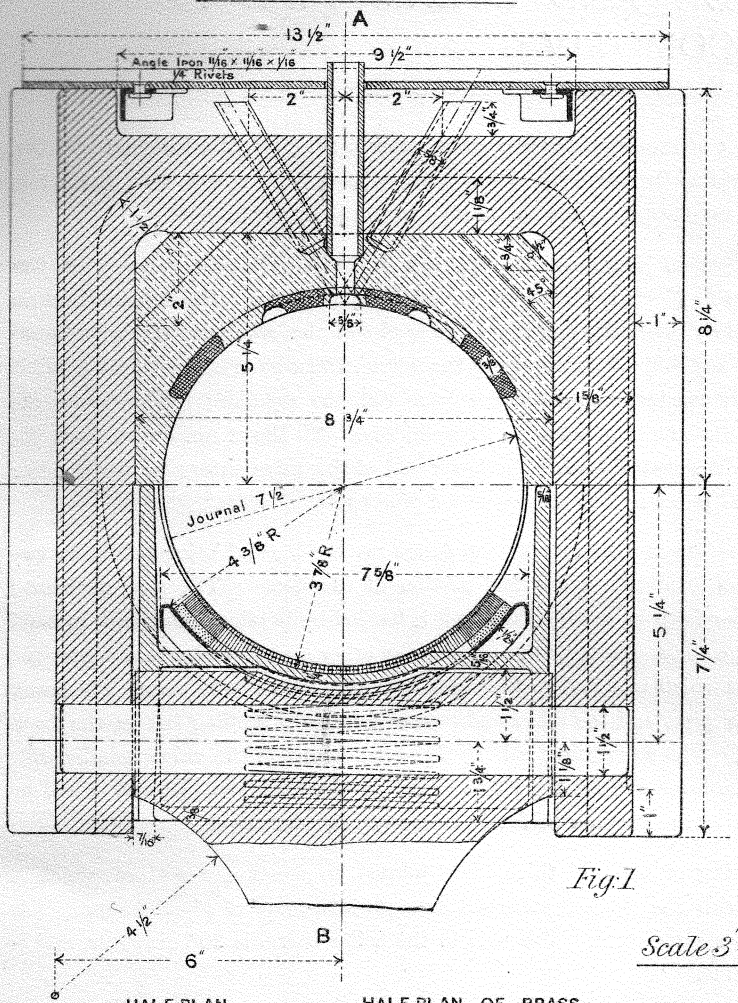


Fig. 1

SECTIONAL ELEVATION AT A. B.

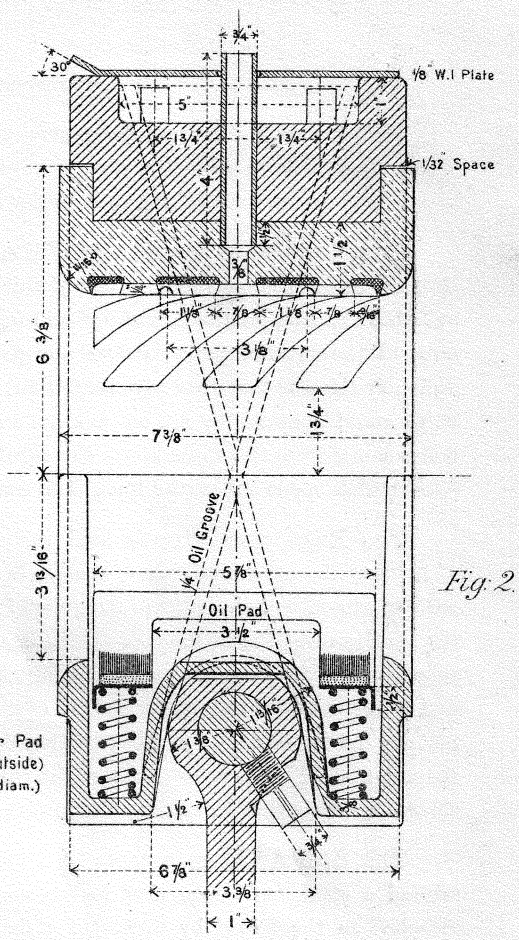


Fig. 2

Springs for Pad
4" x 3/4" (outside)
10. W.G. (.1" diam.)

Scale 3" = 1 Foot.

HALF-PLAN

HALF-PLAN OF BRASS.

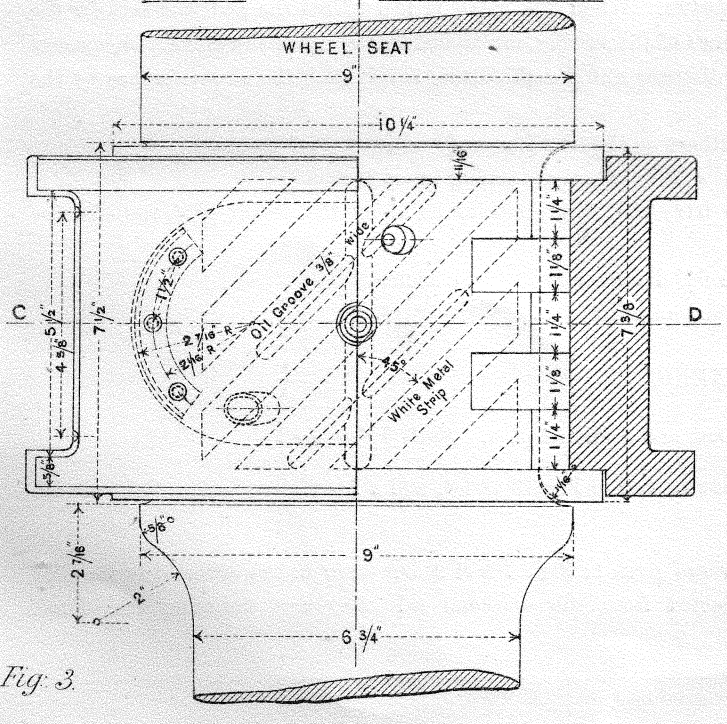
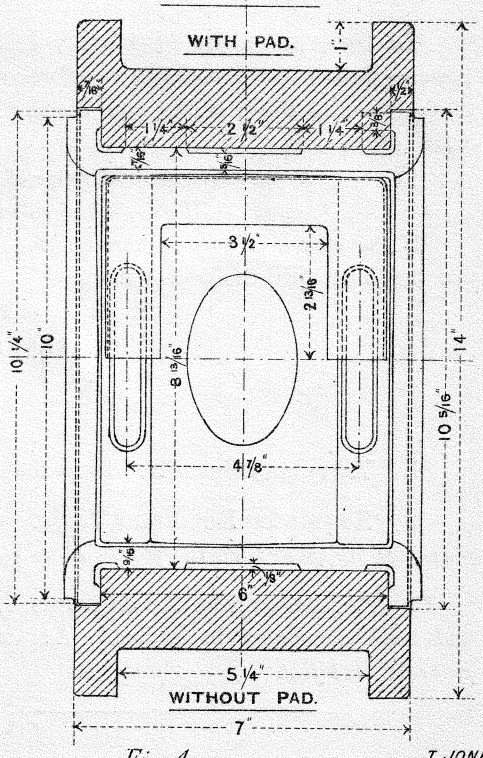


Fig. 3

PLAN OF KEEP.

WITH PAD.



WITHOUT PAD.

Fig. 4

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Plate VII.—REGULATOR AND STEAM PIPE FOR LOCOMOTIVE.

FIGS. 1 and 2 illustrate the general arrangement of the regulator and steam pipe in the dome of a locomotive boiler. The valve, fitted in the regulator head, is placed as far above the water level as possible, to ensure that the steam may be moderately dry as it passes along the regulator and the steam pipe to the engine cylinders.

The Regulator Head and Valve are shown in detail in Figs. 3. and 4. The cast-iron valve is of the **double-beat** type with four wings, $\frac{3}{8}''$ thick, widened to $\frac{3}{4}''$ where they pass through the seatings. The top and bottom ends have effective diameters of $6\frac{1}{4}''$ and $5\frac{3}{4}''$ respectively, so that when the valve is closed the resultant steam pressure on it will be downwards; this does not give rise to any difficulty in opening the valve, whilst even against this possible difficulty there is the great advantage that, should any accident happen to the valve rod, the regulator rod or lever, the valve would immediately fall on its seats and cut off the supply of steam to the cylinders. All the steam drawn from the boiler comes from the space above the regulator since the steam passing the lower end of the valve enters by the annular space which opens out at the top. The cast-iron head is secured to the regulator pipe by six 1″ bolts.

The Regulator Pipe is held vertically in the steam dome by its top flange resting on, and being bolted by two 1″ bolts to the horizontal face of the angle iron riveted inside the cylindrical portion of the dome. The pipe is formed with an elbow, and the vertical flange is of a triangular form to receive the three L headed bolts which are used to hold the brass conical end of the copper steam pipe in the conical mouth of the pipe. The other end of the steam pipe—not shown in the drawing—has a brass flange brazed to it which is bolted to the smoke box side of the tube plate. The crank end of the horizontal regulator rod is carried by the pipe, and the other end passes through a stuffing box in the back plate of the fire-box shell to carry the regulator lever. The connecting rod, $1'-7\frac{1}{2}''$ long, connects the valve spindle with the crank of $1\frac{3}{8}''$ radius, so that a slight turning of the lever will lift the valve. The maximum lift is $1\frac{1}{4}''$, and it will be shown presently that this is more than necessary to give the steam a perfectly free way past the valves.

The Steam Dome consists of a cylindrical ring of steel $\frac{1}{2}''$ thick, butt-jointed, to the upper end of which is riveted a steel angle iron ring for its connection with the flanged spherical wrought-iron cover of $\frac{1}{2}''$ thickness. It is attached to the barrel by means of a flanged base riveted to it. The hole in the boiler barrel is 20″ diameter, and is strengthened with ad internal ring $\frac{3}{4}''$ thick and 7″ wide.

To Determine the Maximum Lift of the Valve. When the valve is lifted from the seat, the area for the passage of the steam is equal to the effective circumference of the seating, multiplied by the lift of the valve. On account of the widened edges of the four wings, the effective distance round each seating is less than the circumference by the width of the wings.

$\therefore$ Effective circumference of the two seatings $= (6\frac{1}{4} + 5\frac{3}{4})\,\pi - (8 \times \frac{3}{4}) = 31{\cdot}7$ inches.

If x = lift of valve, then $31{\cdot}7 \times x$ = effective opening in sq. inches.

If the steam, in passing through the valve, is to have the same velocity as along the steam pipe, the effective opening must equal the area of the pipe.

$\therefore$ $31{\cdot}7x$ = area of circle $6\frac{1}{2}''$ diameter $= 33{\cdot}18$ sq. inches.

$\therefore$ $x = 1{\cdot}04$ inches = maximum lift.

EXERCISES.

1. **Valve and Spindle.** Draw the elevation, plan, and sectional plan. *Scale $\frac{3}{4}$ full size.*

2. **Regulator Head and Valve.** Draw the views given in Figs. 3 and 4, add a front elevation, and also a side elevation projected from the plan. *Scale $\frac{1}{2}$ full size.*

*3. **Regulator and Steam Dome.** Draw the views given in Figs. 1 and 2, but show in the latter view the pipe and head completely in section. Add a plan projected from the sectional side elevation, omitting the dome. *Scale 4″ = 1 foot.*

* This Exercise is intended for Advanced Students.

REGULATOR AND STEAM PIPE FOR DOME OF LOCO: ENGINE.

GENERAL ARRANGEMENT.

FRONT ELEVATION

SIDE AND SECTIONAL ELEVATION

Scale 1 ½" = 1 Foot.

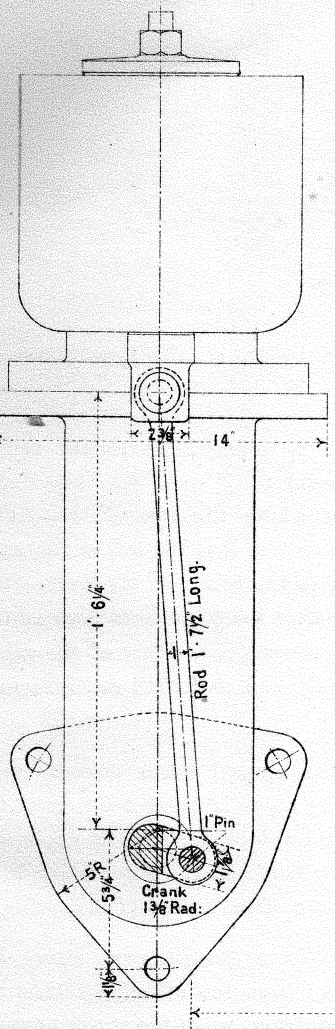


Fig. 1.

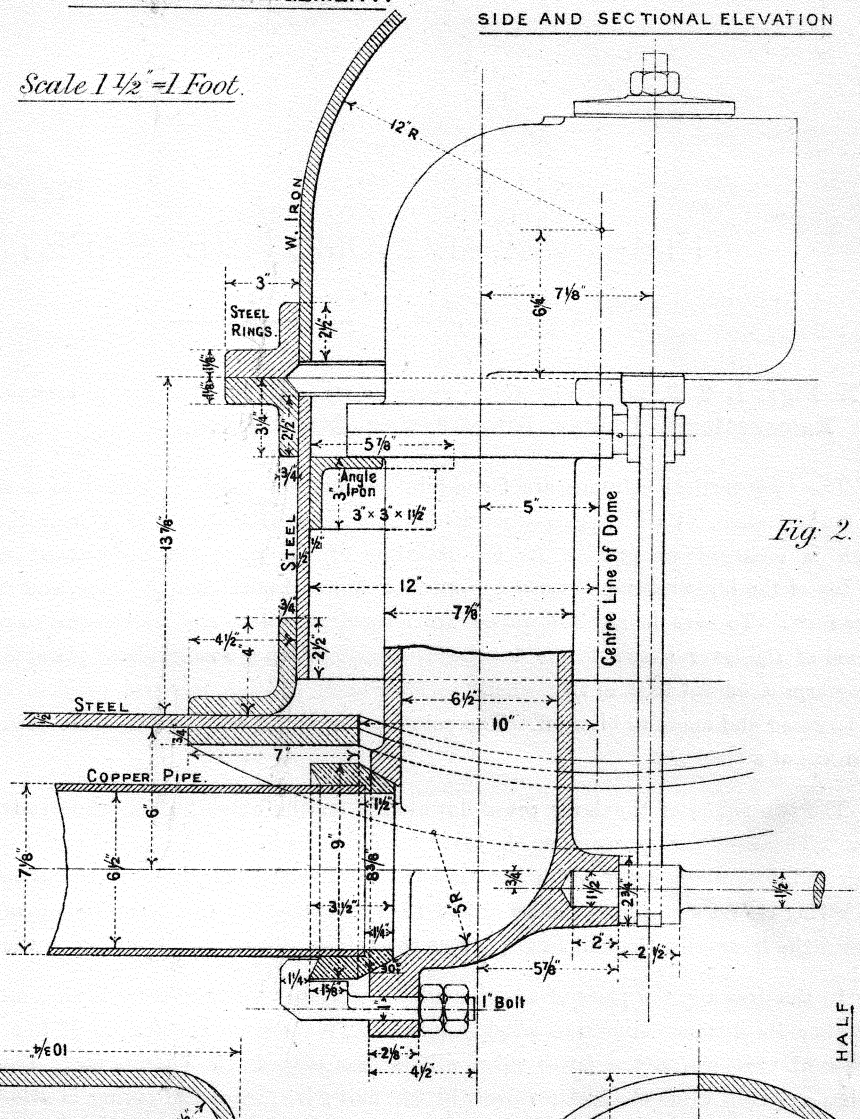
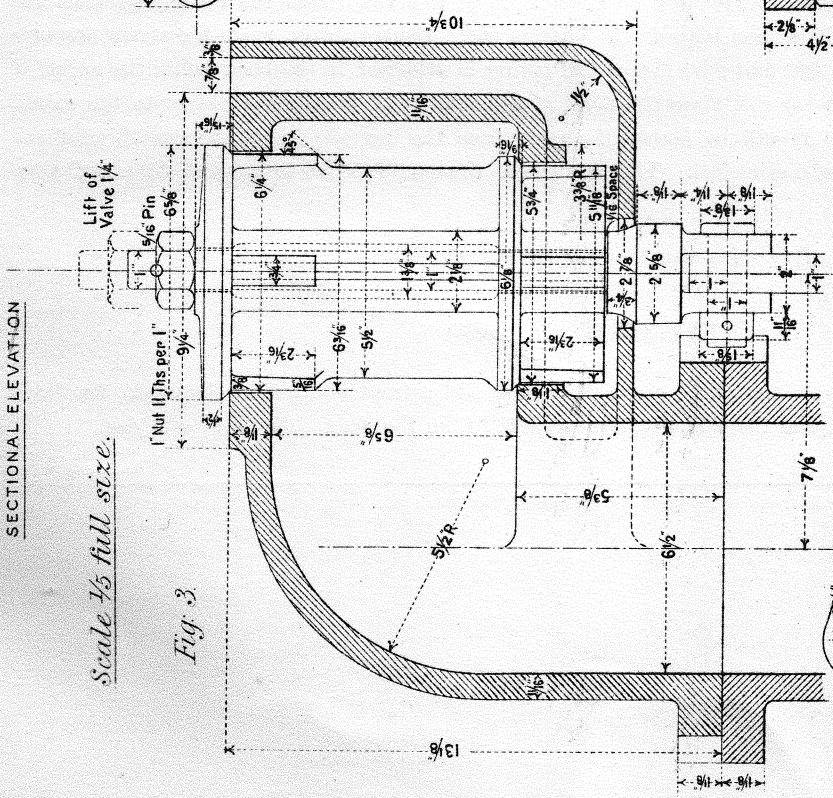


Fig. 2.

REGULATOR HEAD AND VALVE.

SECTIONAL ELEVATION



Scale ¼ full size.

Fig. 3.

HALF SECTIONAL PLAN

HALF PLAN

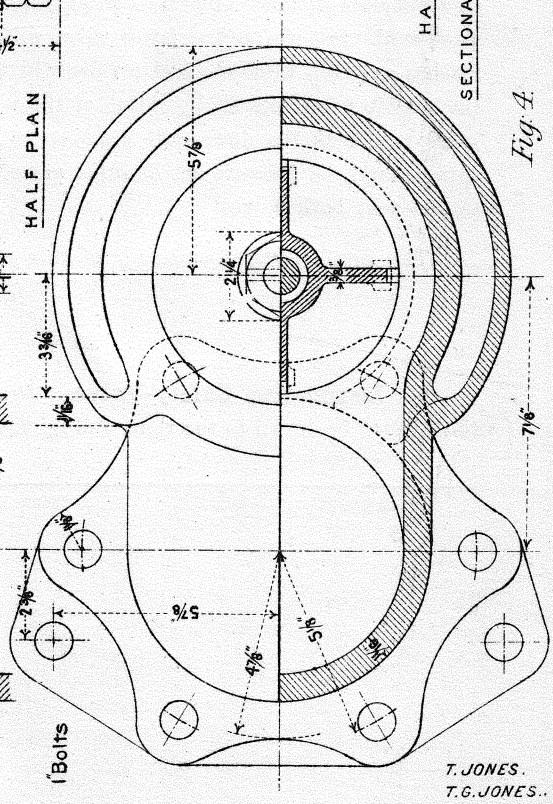


Fig. 4.

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T.G. JONES.

Plate VIII.—LOCOMOTIVE SAFETY-VALVE.

IN Figs. 1, 2, 3, are given three views of the safety-valve for a locomotive boiler, of the type known as **Ramsbottom's Duplex Direct-Acting Safety-Valve.**

The two vertical columns are formed in one casting which is bolted to a steel m unting block on the top of the fire-box shell. Each column increases from an internal diameter of 3″ near the bend to $3\frac{5}{8}$″ near the upper end, which is enlarged to provide for the insertion of the valve seating without diminishing the area of the outlet. The top of the brass seating is turned down to a thin horizontal face $\frac{1}{16}$″ wide, and it is on this that the face of the brass valve rests. To save height the valves are formed with deep conical recesses to receive the points of the lever. The portion of the lever shown in the drawing is stamped from a wrought-iron plate, and, after the edges have been milled, a long arm is welded to it so that when the lever is in position the arm projects into the cab, and either of the valves can be eased and made to blow off. The point at the end of the lever is made separately, and its forked end is secured by means of a steel pin.

The two points of the lever press downwards on the valves, which thus resist the upward steam pressure upon them. The downward pressure on the lever is effected by means of a strong spiral spring which is connected to it at the upper end, and whose lower end passes through the T ended bolt, fixed in the horizontal web between the two columns. The spring is first slung from the lever and then stretched by the screwing up of the bolt below. Two safety links connect the lever with the bolt in order that the valves may not be blown out in the event of the failure of the spring.

In the drawing, the place of attachment of the spring with the lever is shown equidistant from the two valves, but in reality its distance from the outside valve, *i.e.*, the one on the left, is $\frac{1}{8}$″ less than from the other, and thus the downward pressure on the latter valve will be less than on the outside one. Consequently, when the steam pressure reaches a certain value the inside valve will lift first; but, since the spring is attached to the lever below the swivel of the outside point, the slight lifting of the lever will move the point of attachment of the spring nearer to the raised valve, and thus the downward pressure on it will be increased—apart from the increase due to the stretching of the spring—and the pressure on the other valve, diminished. This will enable the outside valve to lift, and steam will then escape past both valves.

The simplicity and efficiency of this safety-valve has brought it into general use

EXERCISE.

*1. **Locomotive Safety-Valve.** Draw the three given views and add a front and a side elevation; the front elevation to be drawn to the right of Fig. 2, and the side elevation projected from the plan. *Scale* 4″ = 1 *foot.*

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* This Exercise is intended for Advanced Students.

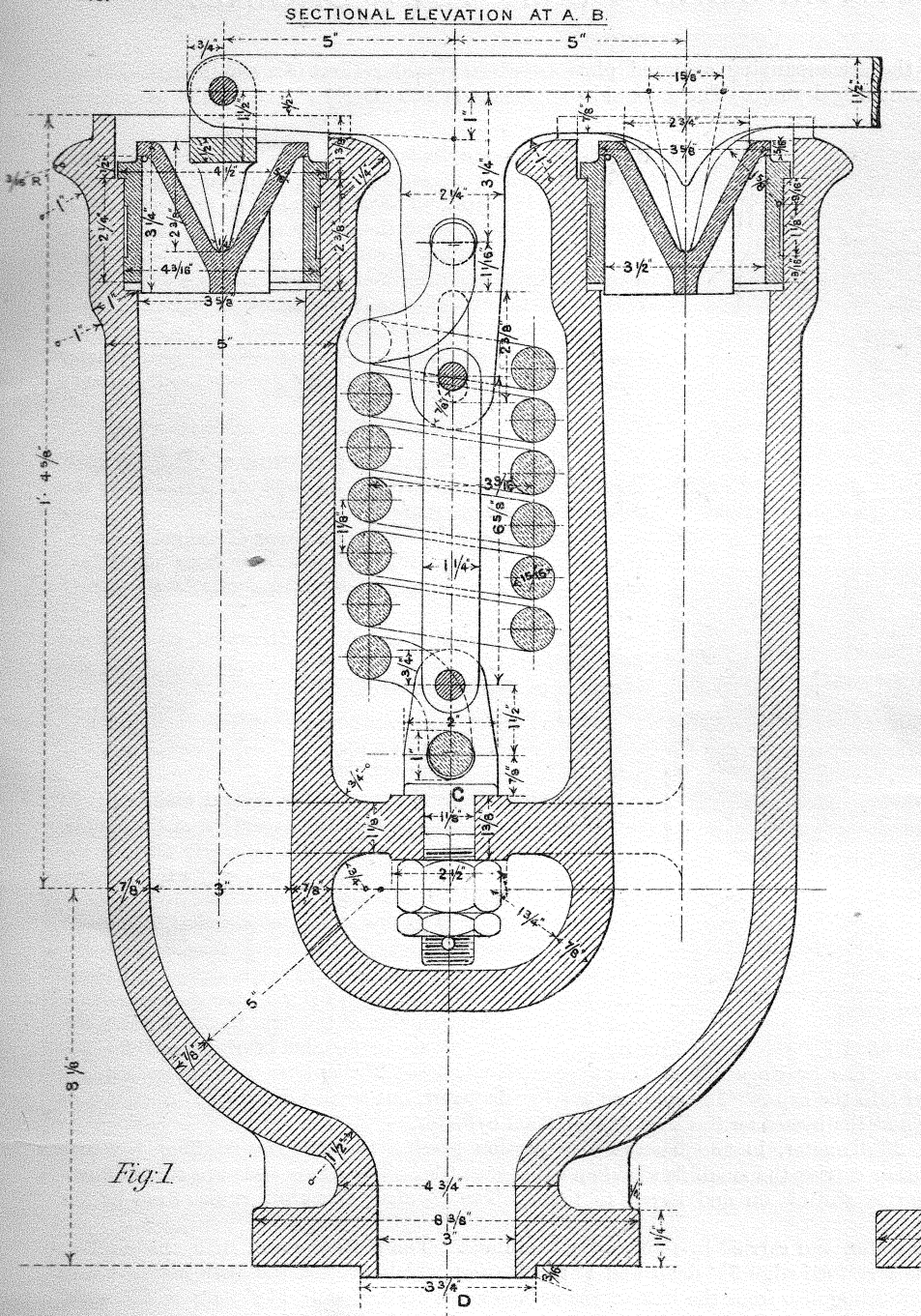

Fig. 1

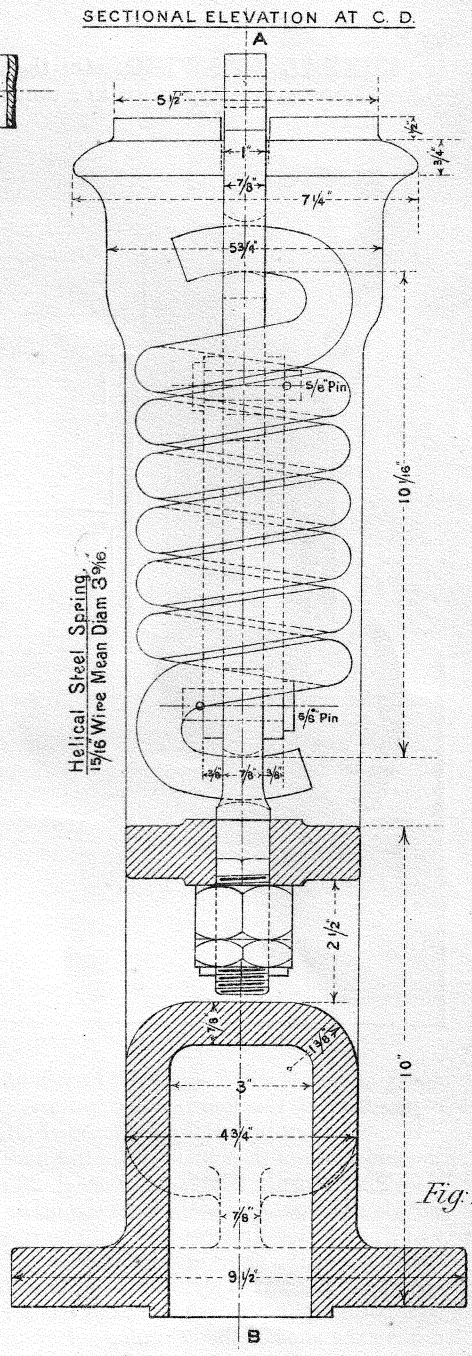

Fig. 2

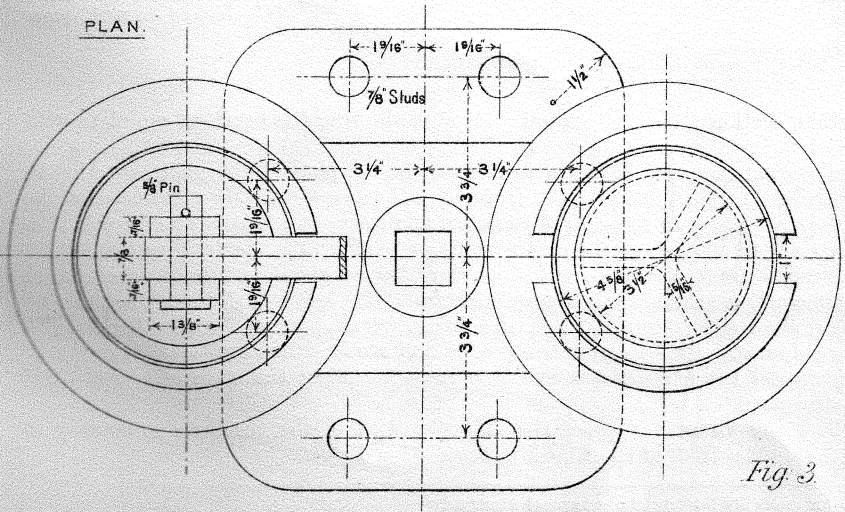

Fig. 3

LOCOMOTIVE SAFETY-VALVE.

Scale 3" = 1 Foot.

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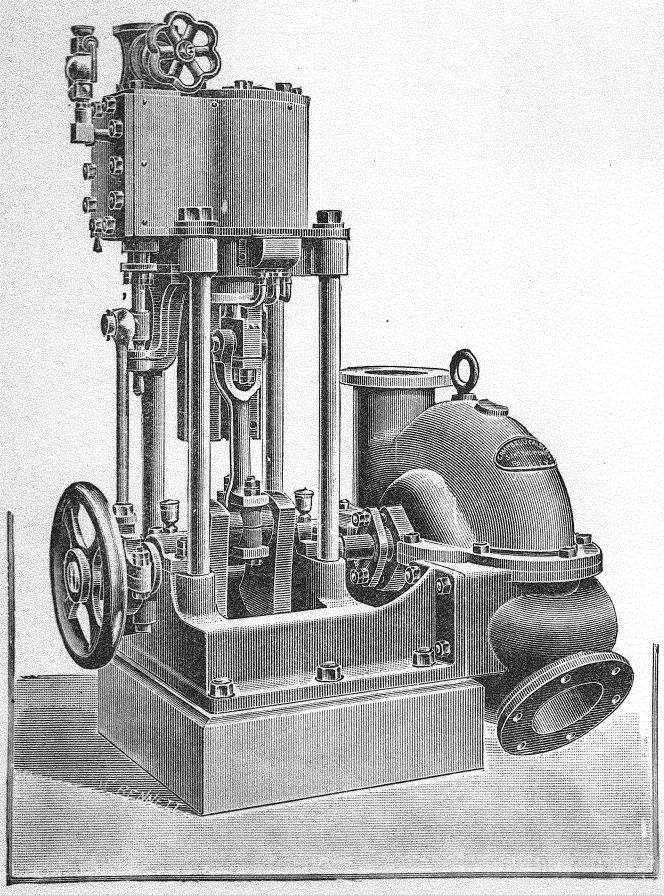
Plate IX.—CENTRIFUGAL PUMP AND ENGINE.

GENERAL DRAWING. On the accompanying coloured plate are given two elevations of a small vertical steam engine coupled up direct to a centrifugal pump. The general arrangement is also clearly shown by the perspective illustration.



The steam cylinder, carried on four steel columns, is 5″ diameter × 6″ stroke, and is supplied with steam through a $1\frac{1}{4}$″ pipe. The slide valve is proportioned to give a late cut-off, since the resistance on the shaft due to the work in the pump is constant and the flywheel is only small. The connecting rod is $13\frac{1}{2}$″ long—$4\frac{1}{2}$ times the length of the crank—and the crank is balanced by a prolongation of the crank webs. Bolted to the side of the engine bed is the pump, which has a wheel 20″ diameter with six vanes, and 6″ diameter suction and delivery pipes.

EXERCISES.

*1. **Complete General Drawing of Engine and Pump.** Draw the front and the side elevations as in the coloured drawing. *Scale* 3″ = 1 *foot.*

If the drawing be made on paper of imperial size, a plan may be added, projected from the front elevation. *Scale* $\frac{1}{4}$ *full size.* For two elevations only, *scale* $\frac{1}{3}$ *full size.*

N.B.—Before this exercise is attempted, those should be drawn which are marked with an asterisk (*) in the exercises to Plates X. and XI.

Plate X.

Details of the Engine. The several views give all the necessary particulars with the exception of the details of the connecting rod. Should any difficulty arise in the designing of the rod, the coloured drawing, Plate IX., may be scaled for the main dimensions.

The Engine Bed is a casting of $\frac{5}{8}$″ metal, with front and back flanges, 1″ thick, for the five $\frac{7}{8}$″ foundation bolts. At one side it is prolonged beyond the bearing and formed with two vertical flanges, each $7\frac{1}{2}$″ × 6″, for the connection of the pump. At each side of the hole through which the crank moves, the bed is raised to a height of $7\frac{7}{8}$″ above the foundation to make provision for the bearings and for the supporting of the four steel columns. The bearings are of ample proportions, being 2″ diameter × 5″ long, and are lubricated from brass oil cups screwed into the caps. The columns are $1\frac{5}{8}$″ diameter, but turned down to 1″ diameter at the ends, where they fit into the bed and the bosses on the base of the steam cylinder.

The Crank Shaft is of steel, 2″ diameter, in two lengths, one portion passing through the stuffing box and carrying the pump wheel, while the other carries the small flywheel and the eccentric. The inside ends are turned down to $1\frac{3}{4}$″, and the wrought-iron crank arms shrunk on and keyed to them. The 2″ steel crank pin is also fixed by the shrinkage of the arms upon it.

The Steam Cylinder is 5″ diameter, and carried by four vertical columns. The bottom cover, with the stuffing box, is cast with the cylinder, and has a vertical edge $3\frac{1}{2}$″ deep and $\frac{1}{2}$″ thick, from which project the four bosses which receive the ends of the columns. Proceeding also from the base of the cylinder is a vertical slab, $11\frac{1}{2}$″ long × $5\frac{1}{2}$″ wide, which receives the pressure of the crosshead.

[*Continued on next page.*

EXERCISES.

1. **Bed Plate.** Draw the side elevation, sectional front elevation and plan, showing the bearings complete with brasses and caps. *Scale* $\frac{3}{8}$ *full size.*

2. **Crank Shaft.** Draw the front elevation, an end elevation to the left, and a plan of the shaft, showing in position the eccentric and the flywheel. Draw, in projection with the front elevation, separate side elevations of the wheel and the eccentric: this will be absolutely necessary in the case of the eccentric before it can be correctly shown in the plan and the front elevation The eccentric is in advance of the crank by an angle of 120°. *Scale* $\frac{3}{8}$ *full size.*

3. **Steam Cylinder.** Draw the sectional front elevation, the side elevation as given and another elevation showing the steam chest with the cover removed, a sectional plan projected from the sectional front elevation and a complete plan. In addition to the cylinder, show the piston and rod, the crosshead support, the slide valve, spindle and bracket, and positions of the supporting columns. Indicate clearly all bolts and studs. *Scale* 4 = 1 *foot.*

N.B.—The above three exercises comprise all the parts of the steam engine—excepting the connecting rod—and form an excellent set for the elementary student.

*4. **Complete Engine.** Draw all the given views, but place the side elevation of the eccentric separately in projection with the front elevation, and add a side elevation of the wheel. *Scale* 3″ = 1 *foot.*

*These Exercises are intended for Advanced Students.

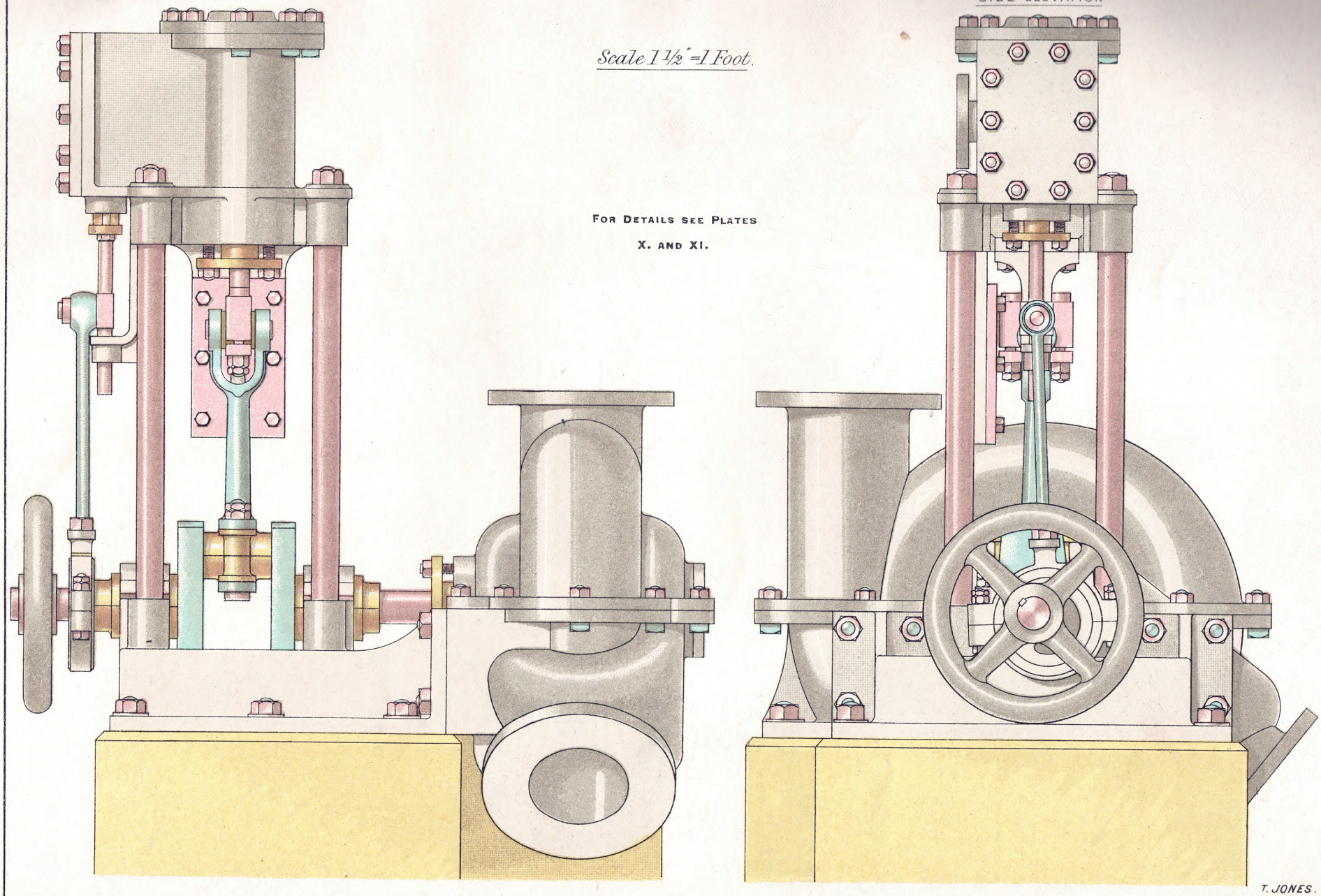
CENTRIFUGAL PUMP AND ENGINE.

FRONT ELEVATION

SIDE ELEVATION

Scale 1 ½" = 1 Foot.

For Details see Plates X. and XI.



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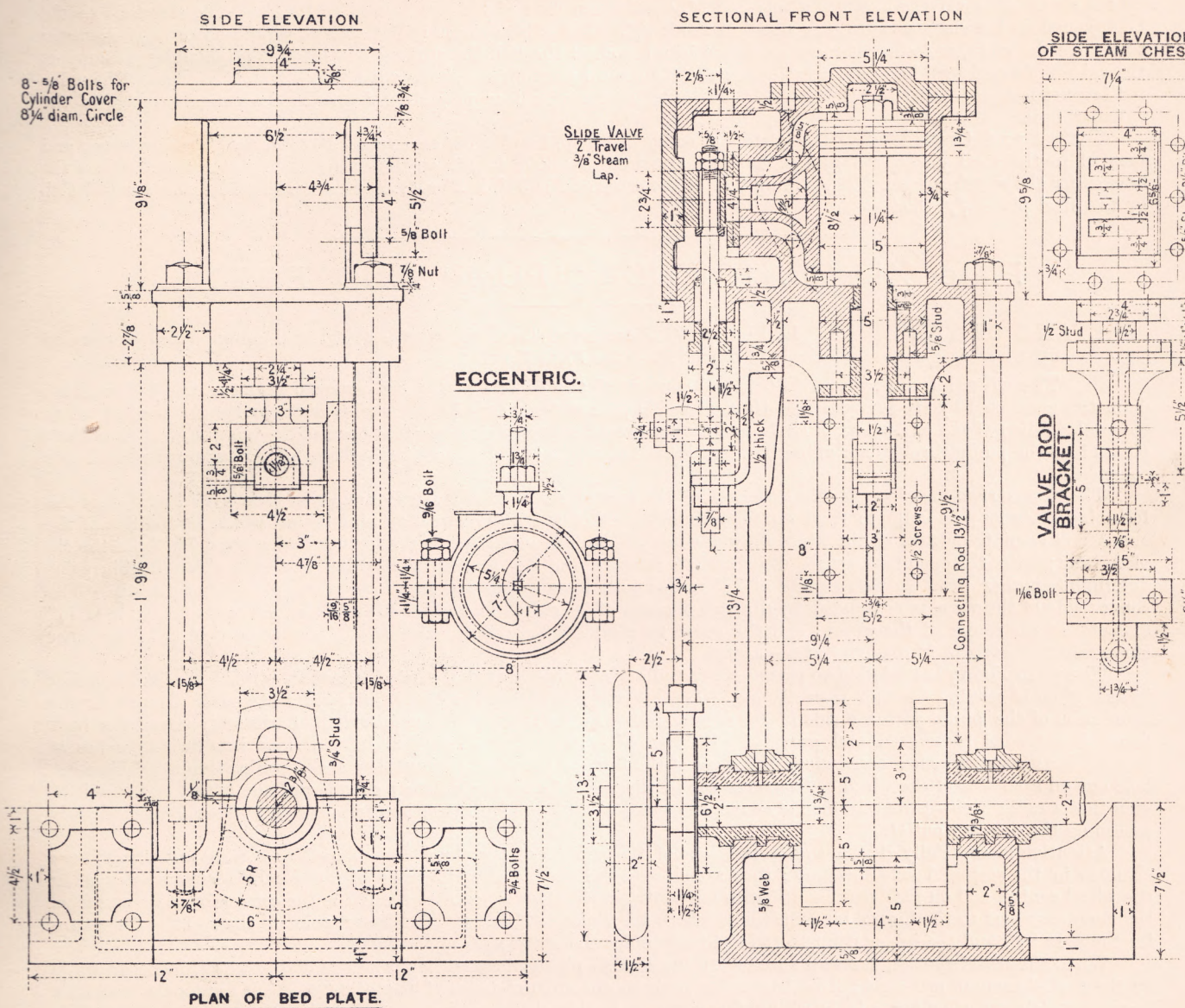
CENTRIFUGAL PUMP AND ENGINE.

DETAILS OF ENGINE.



NOTE: Details of the Connecting Rod are not given, and the minor dimensions omitted from the drawing may be supplied by the Student.

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The steam chest is supplied with steam through a $1\frac{1}{4}''$ diameter inlet; the steam ports are $\frac{3}{4}''$ wide × $2\frac{7}{8}''$ long, and the exhaust port 1″ wide. The exhaust branch pipe is $1\frac{1}{2}''$ diameter and terminates in an oval flange $5\frac{1}{2}''$ × $3\frac{1}{4}''$. For a uniform speed the steam pressure on the piston must be fairly constant, hence a late cut-off is necessary: this is effected by the simple slide valve, which has a travel of 2″, equal steam laps $\frac{3}{8}''$ wide, and no exhaust laps. The eccentric should be adjusted on the shaft so as to give a lead of about $\frac{3}{32}''$. The valve spindle is $\frac{7}{8}''$ diameter, turned down to $\frac{5}{8}''$ diameter to receive the valve, and since it must be passed into the chest through the stuffing box below, the shoulder to support the valve is formed by a loose collar fitting against the conical part of the spindle where the diameter changes. The valve rod bracket is secured by two $\frac{11}{16}''$ bolts to a horizontal rectangular face projecting from the deep circular edge of the cylinder base.

Piston and Crosshead. The piston is solid, $1\frac{3}{4}''$ deep, fitted with two small Ramsbottom packing rings, and secured to the steel piston rod by a nut. The crosshead block is forged on the end of the piston rod and carries the brasses for the crosshead pin. The sliding face of the crosshead is $3\frac{3}{4}''$ × 3″ wide, and is held against the vertical slab by two steel plates $\frac{9}{16}''$ thick.

Plate XI.—CENTRIFUGAL PUMP AND ENGINE.

DETAILS OF THE PUMP. In Figs. 1, 2, 3 are given three views of a centrifugal pump which is coupled up direct with a small vertical steam engine. (See Plate X.)

The wheel is detailed in Fig. 4, and consists of two conical plates, 20″ external diameter and 10″ internal diameter, connected by six curved vanes, three of which pass to the centre for connection with the boss. It is keyed to the prolongation of the engine crank shaft, and fits between the two internal parallel faces of the pump body. The shaft passes into the pump through a stuffing box, and its end is supported in a brass bushed bearing formed on the small side cover.

The necessary dimensions for the drawing of the curved vanes of the wheel are given clearly in Fig. 4, but the following hints may be helpful: mark on the circumference of the outer circle six equidistant points as the tips of the vanes, and from the centre of the wheel draw a circle $3\frac{7}{8}''$ radius, on whose circumference find a point $7\frac{3}{4}''$ from the tip of a vane; with this point as centre draw an arc through the tip, and on the radius produced through this point determine another point so that an arc of $7\frac{3}{8}''$ radius with it as centre will make the vane $\frac{1}{4}''$ thick at the tip. The convex side of the vane is completed by drawing a curve of 5″ radius tangential to the outer curve and a circle of $1\frac{3}{4}''$ diameter at the centre of the wheel; and the curve to complete the concave side is $4\frac{9}{16}''$ radius tangential to the inner curve and the circle of $\frac{3}{4}''$ diameter at the centre.

The pump body is made in two parts—separated horizontally through the axis of the shaft—which are fixed together by ten $\frac{5}{8}''$ bolts passing through their flanges. The lower part is formed with two vertical rectangular flanges for the connection of the pump with the side of the engine bed. As an independent support, the horizontal web of the back flange is extended backwards and provided with two $\frac{7}{8}''$ bolts. The 6″ suction inlet divides into two branches of rectangular section, which proceed along the sides of the body to the centre where they each terminate in a 10″ diameter hole one on each side of the wheel. The space round the wheel forms the delivery chamber of the pump, and it will be seen that a radial web—through which of course the wheel can move—separates the narrowest part from that immediately preceding the delivery outlet.

Attention is especially drawn to the positions of the centres of the three curves used in setting out the delivery chamber in the sectional side elevation; they are all situated on the circumference of a circle $1\frac{1}{2}''$ diameter centred at the wheel centre, and on radii making 45° with the vertical. The lower point to the left is the centre for the curve from the narrowest part to the horizontal centre line, where the space is 2″ wide. The lower point to the right is the centre for the next 90°, and the upper point to the right serves for the completion of the curve.

When the wheel rotates, the water passes up the suction pipe and enters at the centre of the wheel, being drawn in by the partial vacuum produced; it is driven outwards to the circumference of the wheel where it enters the gradually increasing delivery chamber. It is whilst the water is in this chamber that most of its kinetic energy, received from the wheel, is changed into pressure energy, so that, on its arrival at the delivery pipe it has sufficient pressure to rise in the pipe against the head of water. In pumps with backward sloping vanes—as in the drawing—the kinetic energy on leaving the wheel is less than with radial vanes. Before starting it is necessary to fill the delivery chamber with water, so that the suction pipe should be fitted with a rubber-disc foot valve to prevent the water from running back when the pump is standing. The pump is originally filled with water through a hole at the top of the casing, which is afterwards closed by a screwed plug

The absence of suction and delivery valves is a strong recommendation for the centrifugal pump, particularly when the water to be raised is dirty or sandy. This type of pump is only suitable for moderate lifts, seldom greater than 50 ft., with a suction lift of not more than 10 ft; but if worked in series (see the Mather-Reynolds pump on Plates XXXIII. and XXXIV.) the lift may be increased considerably. The **maximum efficiency** is about 65%, but the efficiency varies considerably—sometimes being as low as 30%—if the lift, speed and shape of vanes are not nicely adjusted.

$$\text{In the case of belt driven pumps, efficiency} = \frac{\text{H.P. of raised water}}{\text{H.P. done on shaft}}$$

$$\text{and in direct driven pumps, efficiency} = \frac{\text{water H.P.}}{\text{indicated H.P.}}$$

The latter expresses the combined efficiency of the engine and pump.

EXERCISES.

1. **Pump Wheel.** Draw the sectional side elevation and the sectional plan, Fig. 4, and add an edge elevation. *Scale* $\frac{1}{2}$ *full size.*

*2. **Complete Pump.** Draw the three given views, Figs. 1, 2, 3, add a side elevation, projected from the plan, to the left of that view. *Scale* 3″ = 1 *foot.*

* This Exercise is intended for Advanced Students.

CENTRIFUGAL PUMP AND ENGINE.

DETAILS OF PUMP.

SECTIONAL SIDE ELEVATION

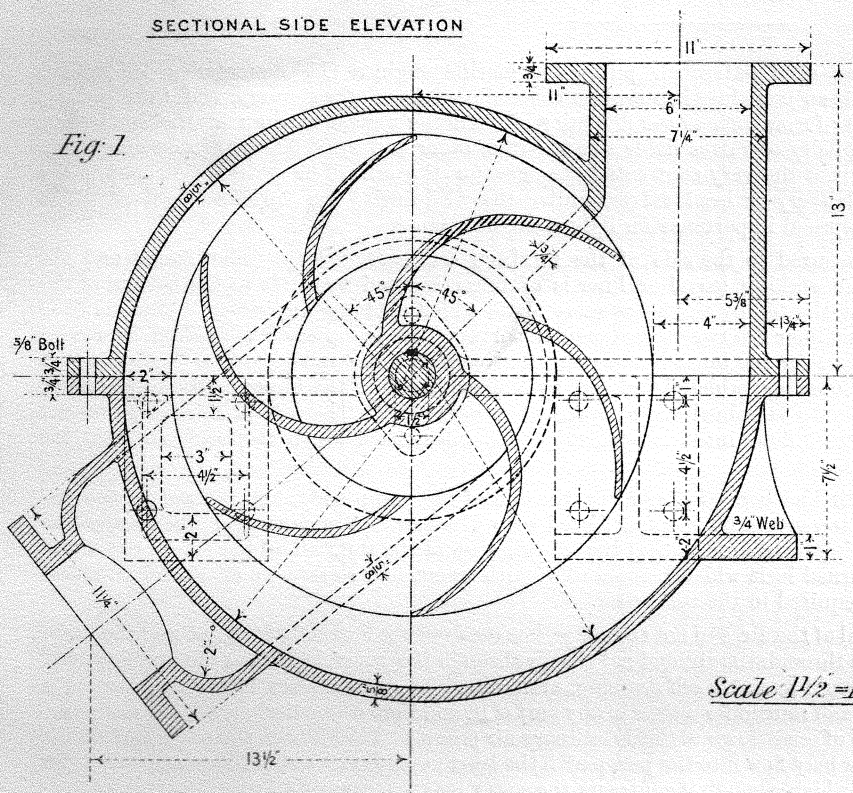


Fig. 1.

SECL. FRONT ELEVATION WITH PLANE THROUGH SUCTION PIPE TURNED INTO THE VERTICAL.

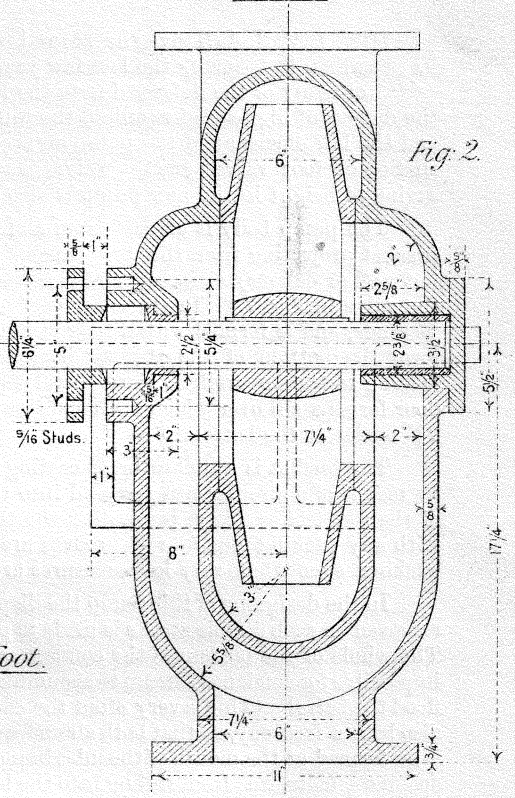
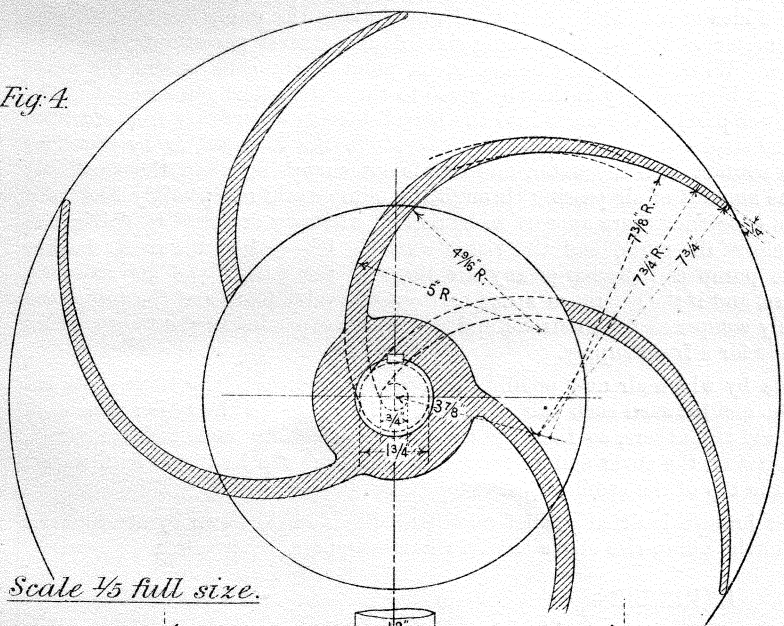


Fig. 2.

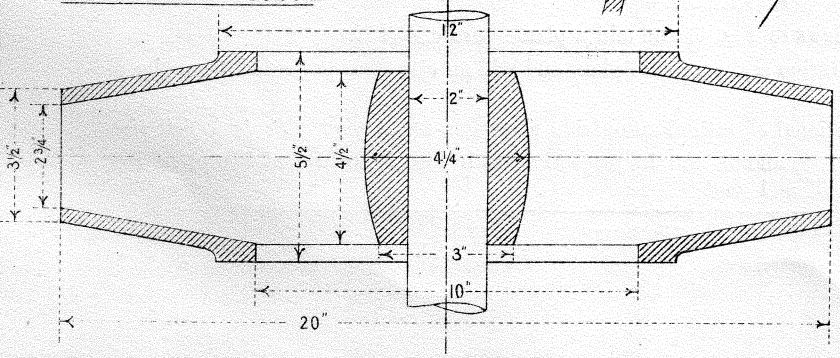
Scale 1½ = 1 Foot.

DETAILS OF WHEEL.

Fig. 4.



Scale ⅕ full size.



PLAN.

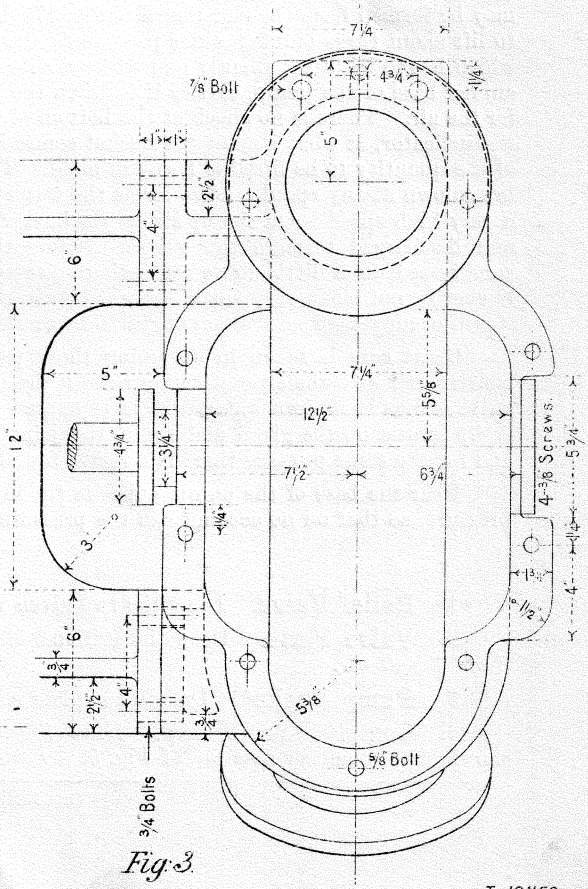


Fig. 3.

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Plate XII.—EDWARDS' AIR PUMP.

FIGS. 1, 2, 3, 4, 5 give the several views of a patent air pump for marine engines (16″ diameter × 16″ stroke) which has, during the last few years, been introduced to replace the ordinary form of air pump, and thus get rid of many of the defects due to the latter form, such as the difficulty of obtaining a good vacuum in the condenser, the danger of high-speed running, the multiplicity of valves liable to get out of order and the difficulty of renewing them, and the low efficiency of the pump on account of the very contracted passages for the air. The ordinary air pump has suction or foot valves, bucket valves, and delivery or head valves, whilst the "Edwards" has only head valves. The saving of height in the new pump is also of special importance on light draught steamers.

The pump body is of cast iron, and is secured to the side of the **surface** condenser by the inlet flange and the bracket projecting from the top flange. The working barrel or liner is of brass, secured by studs to the bottom of the hot well or delivery chamber, and is closed at the top by the brass valve plate, which contains six valves. (See detail of the valve in Fig. 7.) In the lower part of the liner are twelve rectangular ports. The pump cover is secured by twelve $\frac{3}{4}$″ studs, and is formed with a long stuffing box for the brass pump rod. The centre of the valve plate is carried up to form the bottom of the stuffing box. An opening, which is closed by a door, is left in the upper part of the pump leading to the hot well, so that the valves may be examined and renewed when necessary. The curved ridge opposite the door forms a sill over which the condensed steam flows into the open topped chamber, from which it passes through the $2\frac{1}{4}$″ outlet at the bottom.

The bucket is a hollow brass casting with one conical face to fit the end of the pump body, and is fixed to the rod by means of a circular nut recessed into the top of the bucket and locked by a $\frac{5}{8}$″ screw. A small round pin at the end of the rod acts as a key, preventing the turning of the rod during the screwing up of the nut. The bucket is not fitted with any packing, but four $\frac{1}{4}$″ grooves are turned in it which become filled with water, and so form an effective frictionless packing, even when very low pressures are required in the condenser.

In the designing of this pump the disposal of the air, and not the water, has received the first consideration, and the water removed on each double stroke is made to pass through the air, and not the air through the water, as in the ordinary air pump. The whole of the bottom of the condenser should be made self-draining, even when the steamer has a heavy list, making it impossible for condensed steam to accumulate and remain for a time in any part of it, and then when discharged into the pump flood the barrel. (This is very often the cause of breakdown with the ordinary air pump.) The air from the condenser should also have a free way, so that both air and water may flow into the pump with the least possible amount of resistance. A ledge is so formed at the mouth of the inlet branch, which, though it contracts the water passage, prevents foreign matter, such as spanners, bolts, &c., from rolling into the bottom of the pump and thus causing a breakdown. The water flows by gravitation through the inlet branch and over the *guiding edge*, and collects at the bottom of the barrel without any interruption during the ascent and descent of the bucket. Some idea of the small quantity of water which the pump has to deal with may be formed from the fact that a pump, 17″ diameter × 30″ stroke, making sixty double strokes per minute, has only to lift about three pints of water per double stroke. When the bucket descends, the point of the cone enters the water which has to be lifted, silently and without shock; a high velocity is thereby given to the water which, on account of the curved base of the pump, carries it through the lower parts of the ports into the barrel, leaving a perfectly free entrance for the air. There is no shock at the bottom of the stroke, it being impossible to detect in the diagram, or by watching the indicator, at what instant the bucket comes in contact with the water, and this is not surprising when the smallness of the quantity to be lifted is borne in mind. The amount of air passing through the pump could not possibly lead to a breakdown at any speed, and so far as the water is concerned there appears to be no risk whatever attached to driving at a very high speed. On the up-stroke the bucket closes the ports, and the rising water is followed by the rising bucket and discharged through the valves. Before the pump can discharge any air through the valves the air must be compressed to a little above atmospheric pressure, and if the clearance space between the valve plate and the top of the bucket be not made very small, air will be uselessly compressed each stroke, and afterwards expanded in the pump, where it will occupy the space which ought to be available for a fresh supply.

Great care is taken in designing those parts by which air may possibly leak into the pump. The valve seats are constructed with the strengthening ribs on the top, one between each pair of valves, and a lip round the edge; thus each valve stands in its own water, and is separated from the others, so that tightness of each can be seen and compared. A lip is cast on the gland and round the joint between the cover and valve-seat, so that each can be tested with water; and for the same purpose there is a recess round the top of the stuffing-box.

Near the base of the pump, opposite the inlet branch, is fitted a relief valve (see Fig 6) held down by atmospheric pressure, so that on no account can the pressure in the pump rise above that of the atmosphere.

EXERCISES.

1. **Relief Valve.** Draw the two given views of Fig. 6, and add a plan. *Scale full size.*

2. **Valve Plate.** Draw the sectional elevation and complete plan, and add an elevation projected from the plan. *Scale* $\frac{1}{2}$ *full size.*

3. **Pump Bucket.** Draw a complete sectional elevation, an outside elevation, and a plan. *Scale* $\frac{1}{2}$ *full size.*

*4. **Complete Air Pump.** Draw Figs. 1, 2, and 3, and in projection with Fig. 1, draw and complete Fig. 4, showing as much as possible of Fig. 5. *Scale* 3″ = 1 *foot.*

* This Exercise is intended for Advanced Students.

EDWARDS' PATENT AIR PUMP FOR MARINE ENGINE.

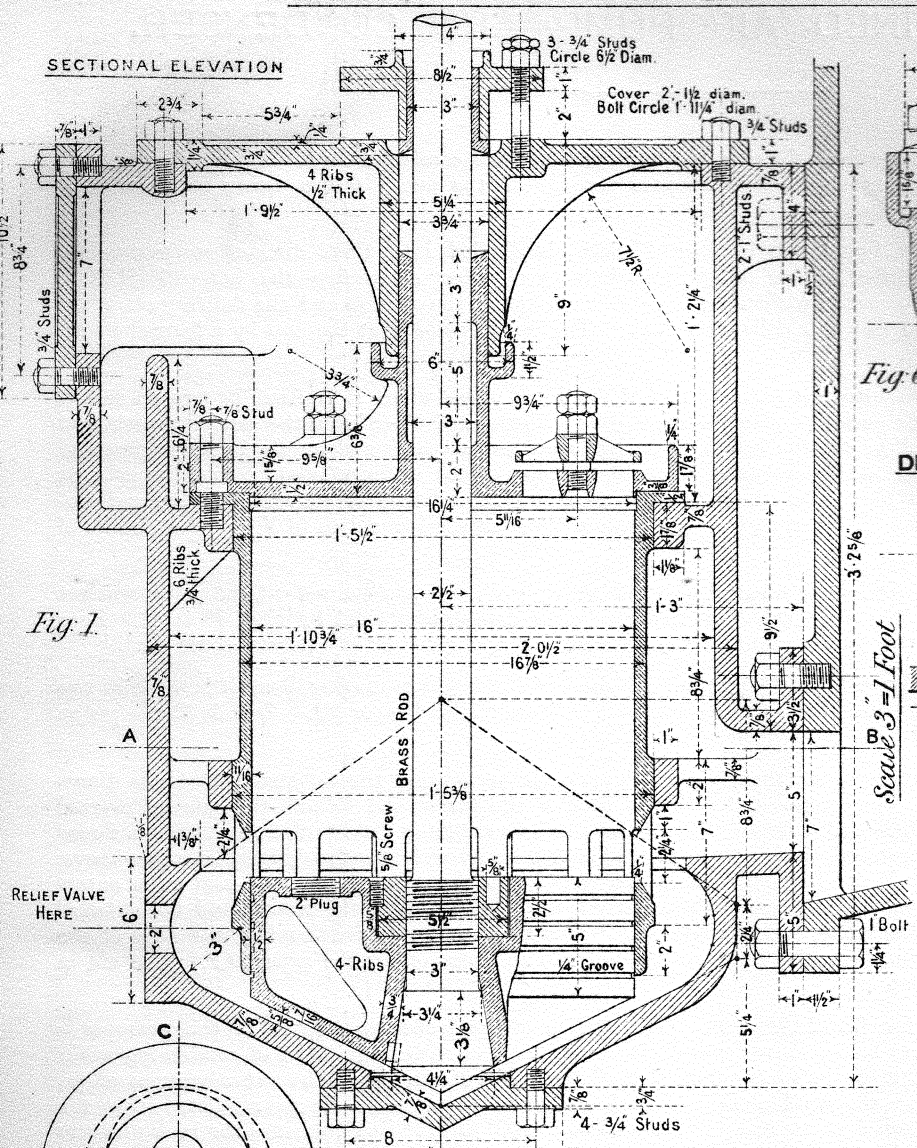

Fig. 1.

Scale 3" = 1 Foot

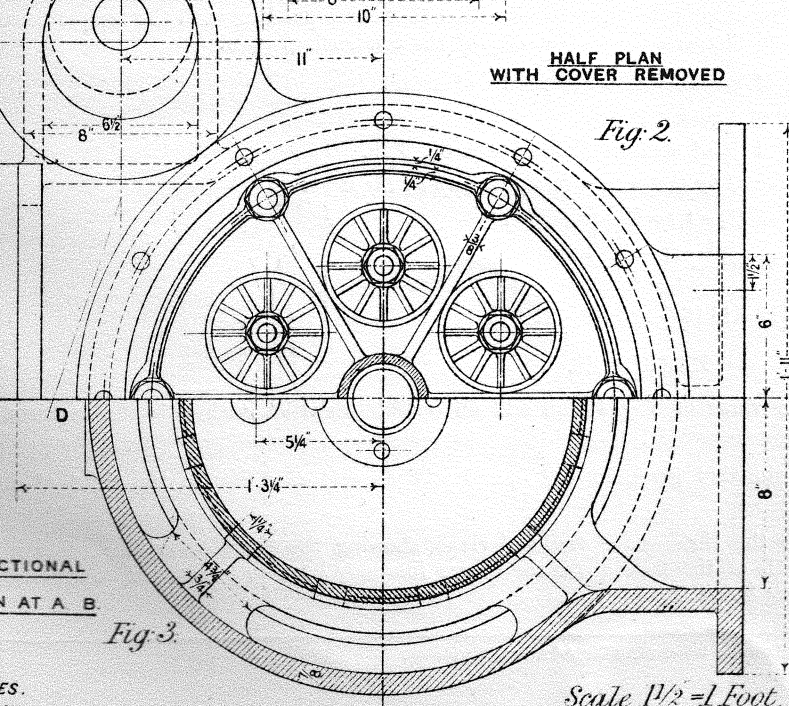

Fig. 2.

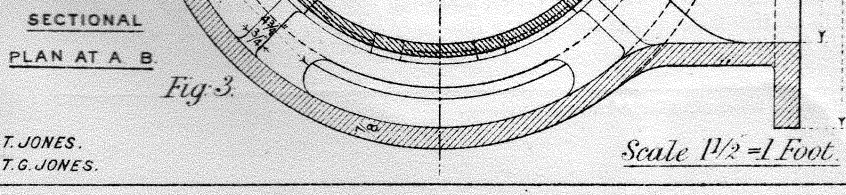

Fig. 3.

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Scale 1 1/2 = 1 Foot

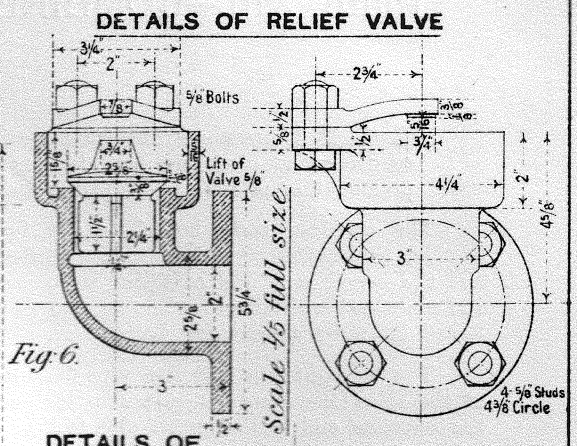


Fig. 6.

Scale 4/5 full size.

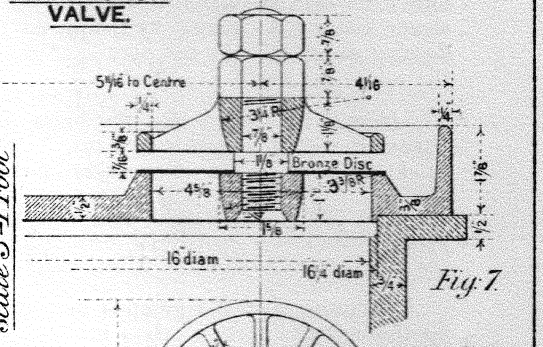
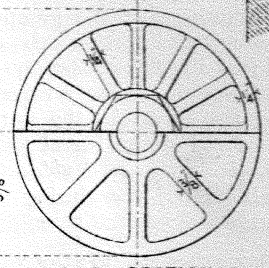


Fig. 7.



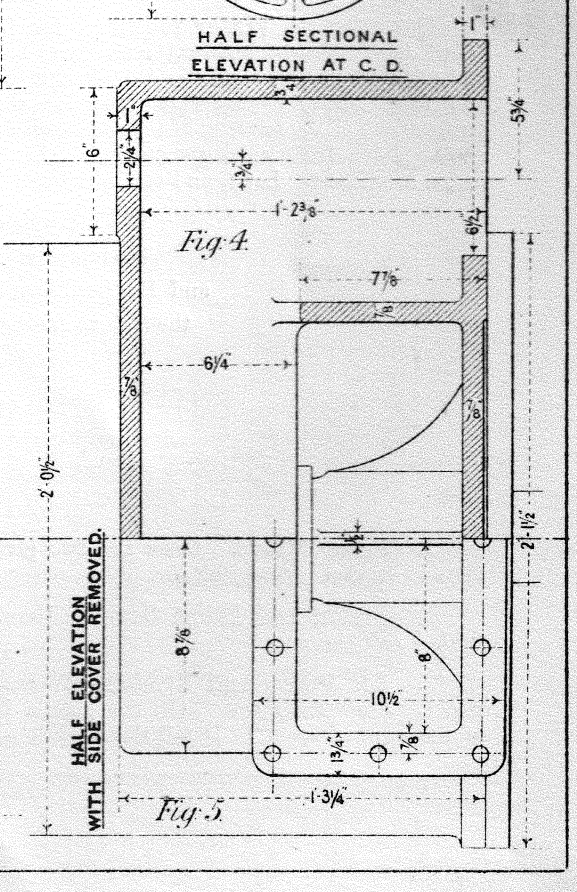


Fig. 4.

Fig. 5.

Plate XIII.—COMBINED AIR PUMP AND CONDENSER.

FIGS. 1, 2, 3, are three important sections showing the construction of a combined double-acting air pump and condenser as used for a condensing engine where space permits of the pump piston being attached to a prolongation of the engine piston rod.

The cast-iron body, bolted to the foundation by four 1″ bolts, is divided into three distinct compartments, namely, the condenser and suction chamber of the pump; the delivery chamber containing the hot-well (H.W.); and the barrel, each end of which is connected with a separate space between the suction and the delivery chamber, and connected with them by two suction and two delivery valves. The body is closed at the top by a flanged cover, bolted down by eighteen $\frac{5}{8}$″ bolts.

The wrought-iron injection pipe fits into the enlarged end of the inlet pipe—where it is fixed by two set screws at the sides (these are not shown in the sectional plan)—and projects a distance of 3′ – 8″ into the condenser, while at the opposite end is the steam pipe (S.P.), and the steam inlet. The cold water passing along the injection pipe and into the condenser chamber through the numerous small holes in the pipe, comes in direct contact with the exhaust steam which has entered by the steam pipe; the steam is condensed, and the mixture of condensed steam and condensing water falls to the bottom of the chamber, and collects below the four suction valves (S.V.) (For details of the valves see Fig. 4.)

It will be noticed that the brass grid beds upon a thin rubber ring which makes a water-tight joint without "trueing up" the cast-iron faces. The four sides of the condenser are strengthened by ribs, $\frac{3}{4}$″ thick. Four hand-holes and covers on one side of the pump admit of the examination and renewal of the valves.

The pump barrel is fitted with a brass liner, 7″ internal diameter, and the piston moving along it is made in two parts, packed with hemp and attached to the brass rod by means of a brass nut and taper pin. Details of the piston are given separately in Fig. 5, and also of the front cover and stuffing box.

Assuming that the pump is in working order, then, while the piston is performing the *out* stroke, water is drawn up through two suction valves into the space connected with the back of the barrel, and follows the outward moving piston; at the same time, the water which had collected during the previous stroke at the front of the piston is forced through the two delivery valves (D.V.), connected with the front end of the barrel and into the delivery chamber above. During the *in* stroke the water at the back of the piston is discharged into the delivery chamber, and water enters the front end of the barrel through two suction valves. Since water is discharged during the inward and the outward stroke, the pump is *double-acting*. The water stands above the delivery valves up to the level of the edge of the hot-well (H.W.), and during each stroke a quantity falls into the hot-well and runs off by the pipe (D.P.); the air in the pump also escapes through this outlet.

Quantity of Water required for Condensation. The system of condensation adopted in this example is called *Jet Condensation* since the steam to be condensed comes into actual contact with the cold jet of condensing water and mixes intimately with it. On account of the evolvement of the latent heat of the steam, the water becomes warm, and the quantity of water required for the condensation of each pound of steam must be so regulated that the temperature of the mixture in the condenser does not exceed a certain limit (100° to 110° Fah.), because the back pressure on the piston from which the steam is exhausting cannot possibly be less than that corresponding with the temperature in the condenser. Let t_1 and t_2 = initial and final temperature respectively of the condensing water.

W = lbs. weight of condensing water per lb. of steam

T = temperature of exhaust steam

and H = total heat of 1 lb. of steam reckoned from 32° Fah.

then, since *Heat received by the water = heat given up by the steam*

$$W(t_2 - t_1) = H - (t_2 - 32°)$$

$$\text{or } W = \frac{H - (t_2 - 32°)}{t_2 - t_1}$$

$$[H = 1146{\cdot}6 + {\cdot}3\ (T - 212°)].$$

EXERCISES.

1. **Pump Valve.** Draw the two given views of Fig. 4, and add an outside elevation with only the cast-iron plate in section. *Scale full size.*

2. **Piston and Front Cover.** Draw the view given in Fig. 5, and add an end elevation to the right of it. *Scale $\frac{1}{2}$ full size.*

*3. **Air Pump and Condenser.** Draw the three given sectional views, showing the front cover in section in Fig. 1. *Scale 2″ = 1 foot.* (In the plan, a little of the base above the centre line may have to be omitted on account of the want of space.) Detail the valve to *scale $\frac{1}{3}$ full size.*

*This Exercise is intended for Advanced Students.

SECTIONAL ELEVATION AT E. F

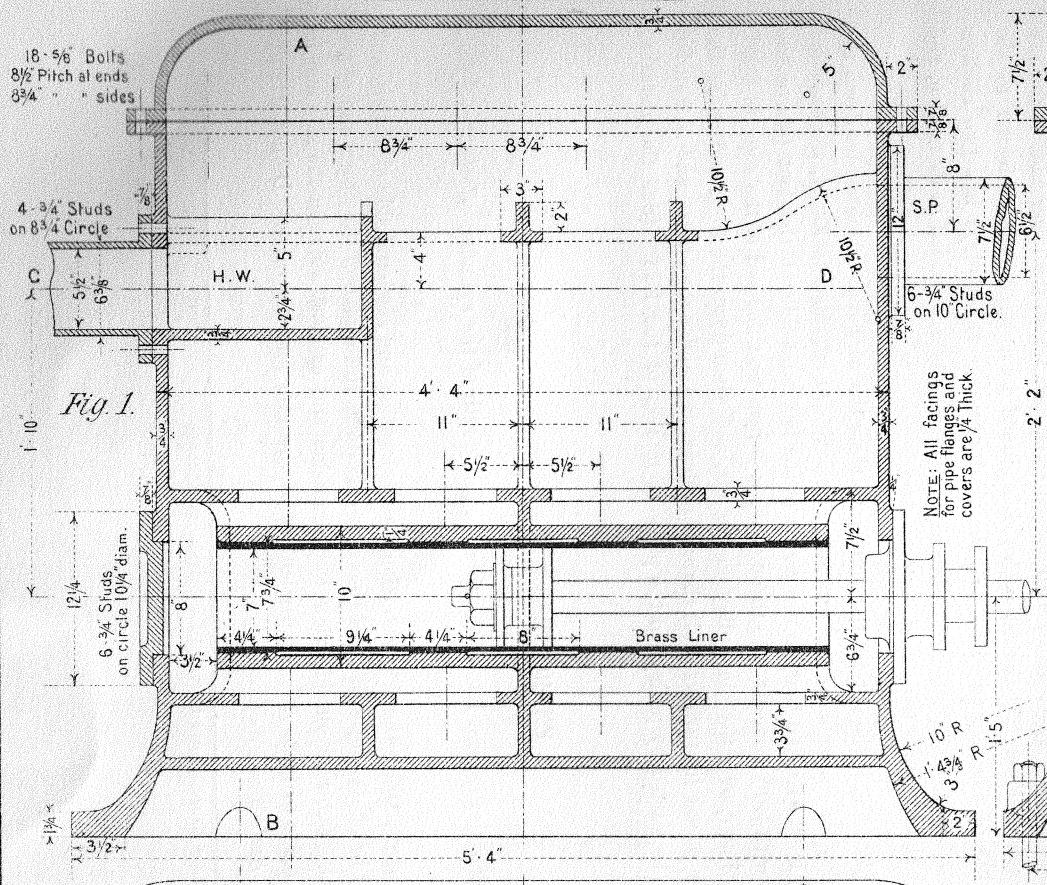


Fig. 1.

SECTIONAL ELEVATION AT A. B

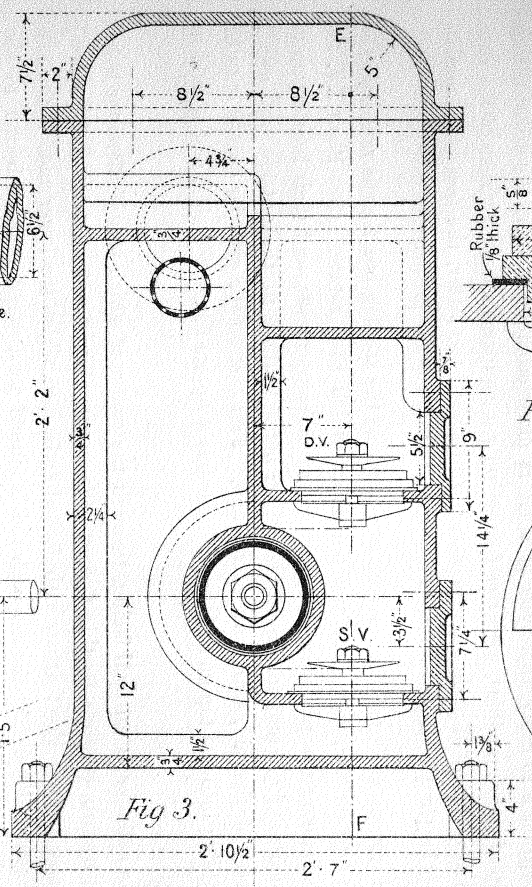


Fig. 3.

DETAILS OF VALVE.

Scale ¼ full size.

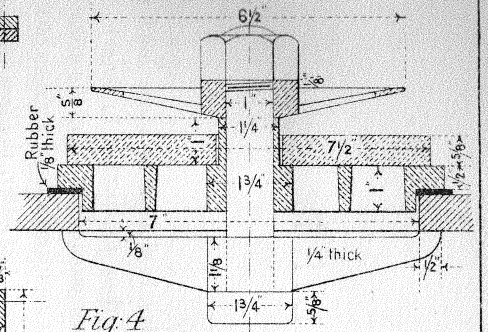
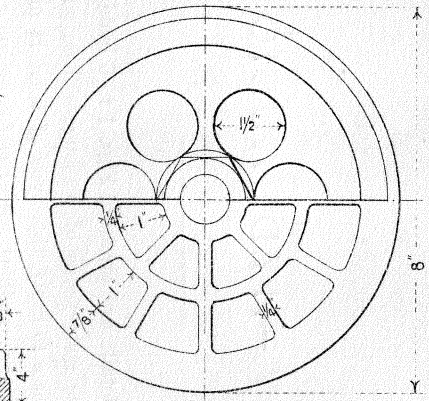


Fig. 4



SECTIONAL PLAN AT C. D.

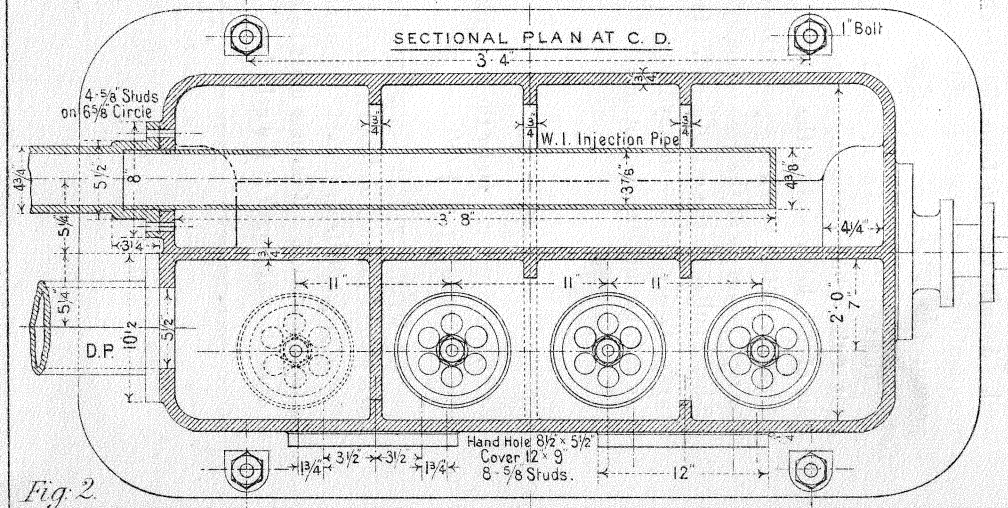
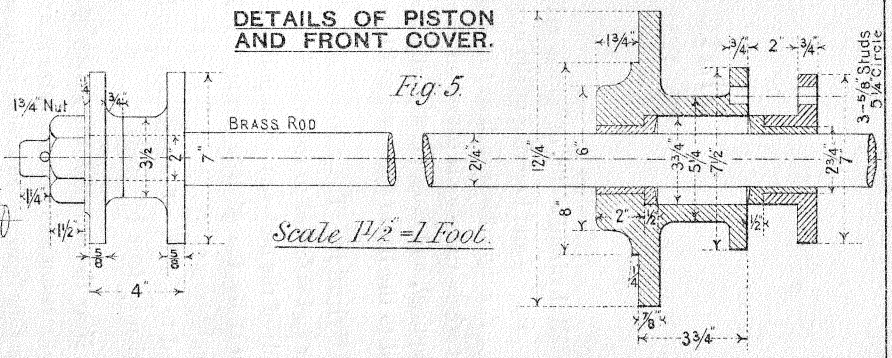


Fig. 2.

DETAILS OF PISTON AND FRONT COVER.

Fig. 5.



Scale 1½" = 1 Foot.

COMBINED AIR PUMP AND CONDENSER.

Scale ⅞" = 1 Foot.

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Plate XIV.—HYDRAULIC LIFT.

THE hydraulic lift, of which cylinder details are given in Figs. 1 to 6 inclusive, is similar to those used for the raising and lowering of the cage for the conveyance of passengers from one floor to another in large buildings. For light loads such as the cage will have to carry, this type of hoist is more economical than the direct-lifting hoist where the cage is placed on the top of the ram; since, with the former, only a comparative short stroke of the ram is required, and consequently only a small quantity of high-pressure water, whilst with the latter, the ram has a motion equal to the lift of the cage, and hence a larger quantity of water is required, but of a lower pressure.

Cylinder. The cast-iron cylinder has an enlarged square end which forms the stuffing box for the ram, and the other end is forked to receive three wire rope pulleys, and carry the pin about which they rotate. (See Plate XV. for details of the pulleys.) The pulleys are loose on the pin since they all run at different speeds, and their lubrication is effected by the $\frac{3}{8}''$ hole through the centre of the pin, and the three branch holes leading to the outside. A small wrought-iron elbow, screwed into the end of the pin, serves as an oil cup. Feet cast on the cylinder enable it to be bolted to a wall. The cast-iron gland fitting into the top end of the cylinder has a square flange $9\frac{3}{4}''$ side, and is held in position by four $1\frac{1}{8}''$ studs.

Near the centre of the length of the cylinder is an oval facing, through the centre of which is a $\frac{7}{8}''$ diameter hole: the admission and exhaust valve is fixed by two $\frac{3}{4}''$ studs to this facing. (See next plate for the details of the valve.) Projecting from the two sides of the square end are short arms, with forked ends, into which the lower ends of the two guide rods are fixed by $\frac{5}{8}''$ pins driven across them. At the top each rod is pinned to a small bracket bolted to the wall. As will be seen from the drawing of the ram on Plate XV., the head carrying the pulleys has two shallow rectangular slots at its sides, and it is by the guide rods fitting into these that the ram is guided in its motion, and prevented from turning. The T ends at the top limit the lift of the ram.

The two $\frac{3}{8}''$ screws at A and B are placed a little out of the centre to clear the wire rope which comes down the front of the cylinder from the centre pulley on the ram to the centre one below. On reference to Fig. 4, the sectional plan of the lower end of the cylinder, it will be seen that, in the corner of the left-hand side of the foot (above the centre-line in this view), is a projection with a 1″ diameter hole through it: it is here that one end of the rope is fixed. The rope passes up at the back of the cylinder, over the ram pulley on the left, and then down the front and under the left-hand pulley on the cylinder end. It passes in turn over all the ram pulleys, and under the others, and is then led away vertically behind the cylinder, to be guided by pulleys to the place of motion of the load. (See the notes to Plate XV. for further explanation.)

EXERCISES.

*1. **Cylinder.** Draw the five given views, Figs. 1 to 5, showing the full length of the cylinder. *Scale* 2″ = 1 *foot.* Detail of screw, Fig. 6, $\frac{3}{4}$ *full size.*

*2. **Cylinder and Ram complete.** Draw the side elevation, front elevation and sectional side elevation, and also a plan of the ram end and guide rod brackets projected from the front elevation, and a plan of the upper end of the cylinder projected from the side elevation. Show in outside view the admission and exhaust valve in the side and in the front elevation. Reference must be made to Plate XV. for particulars of the ram and the valve. Do not attempt to show the full length of the cylinder. *Scale* 2″ = 1 *foot.*

* These Exercises are intended for Advanced Students.

HYDRAULIC LIFT.

DETAILS OF CYLINDER.

Scale 1¼" = 1 Foot.

SIDE ELEVATION

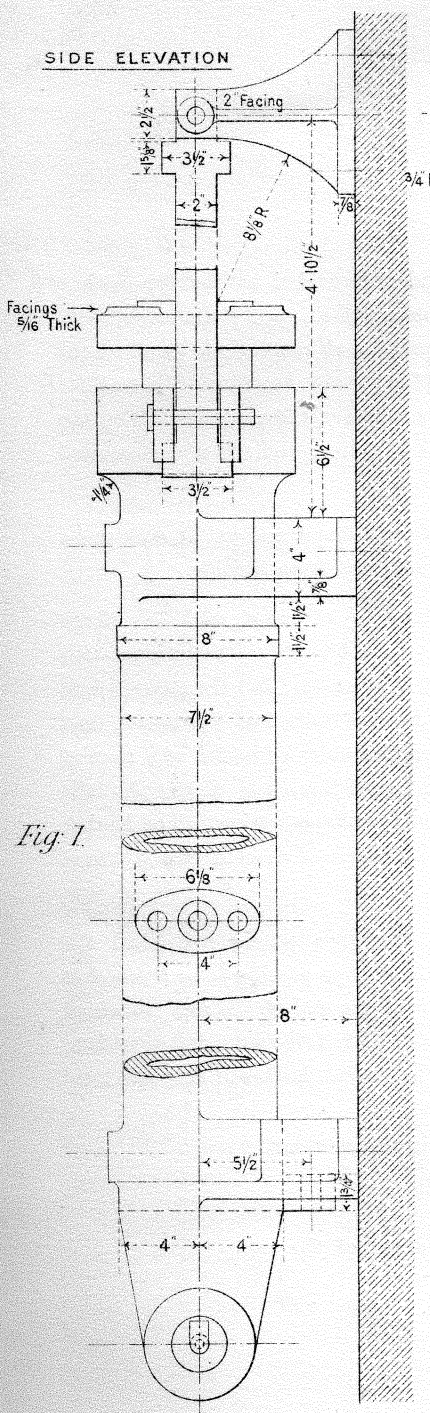

Fig. 1.

FRONT ELEVATION

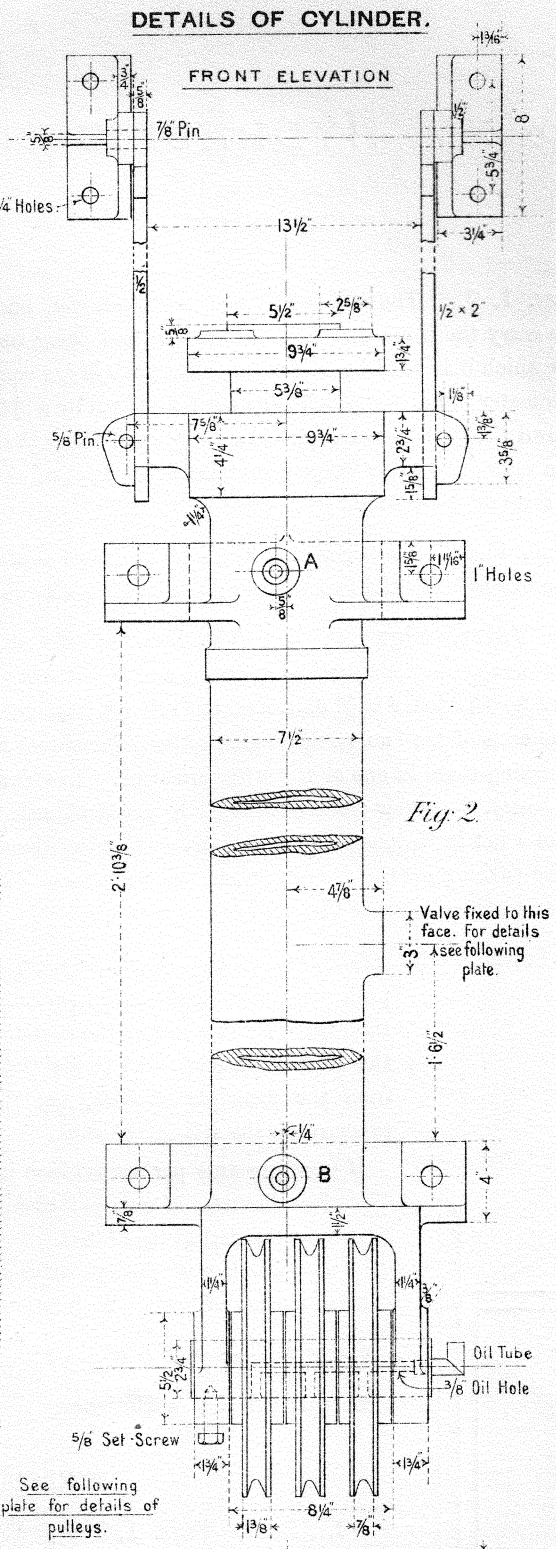

Fig. 2.

SECTIONAL SIDE ELEVATION

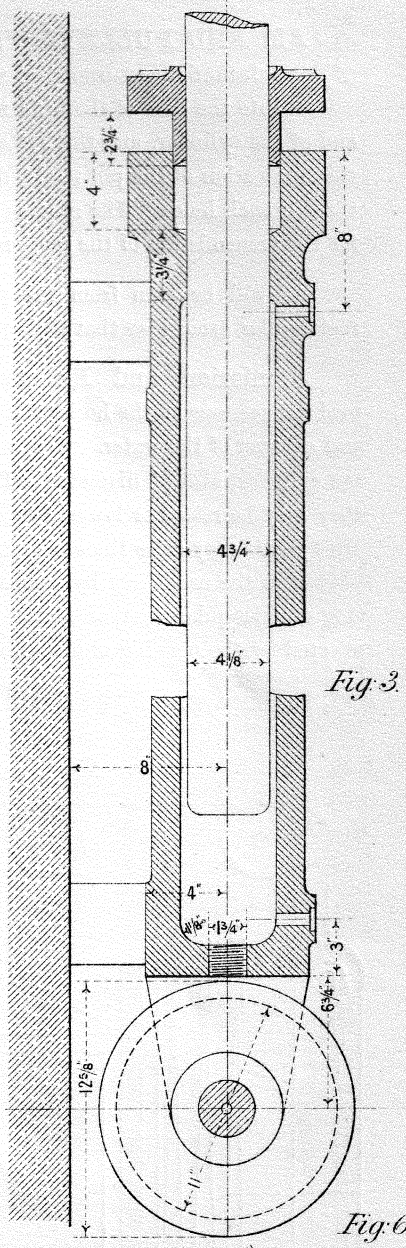

Fig. 3.

SECTIONAL PLAN OF LOWER END.

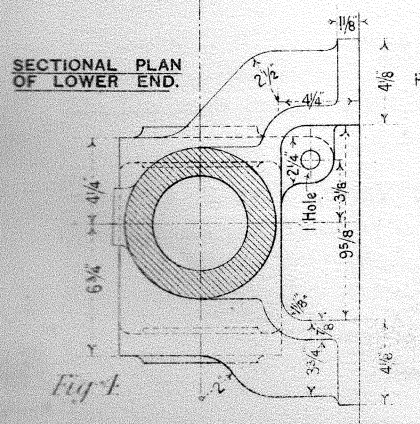

Fig. 4.

See following plate for details of pulleys.

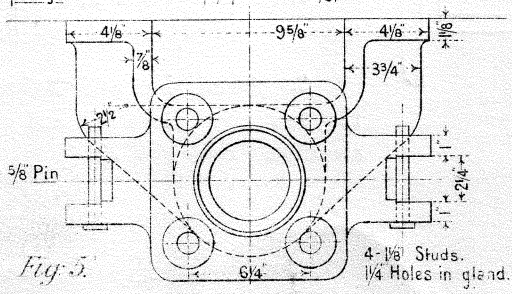

Fig. 5.

PLAN OF UPPER END

DETAIL OF SCREW, AT "A" AND "B"

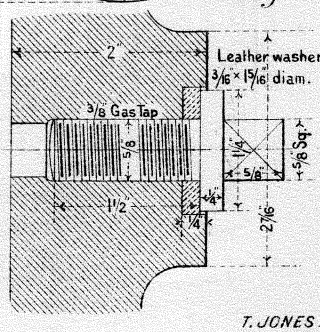

Fig. 6.

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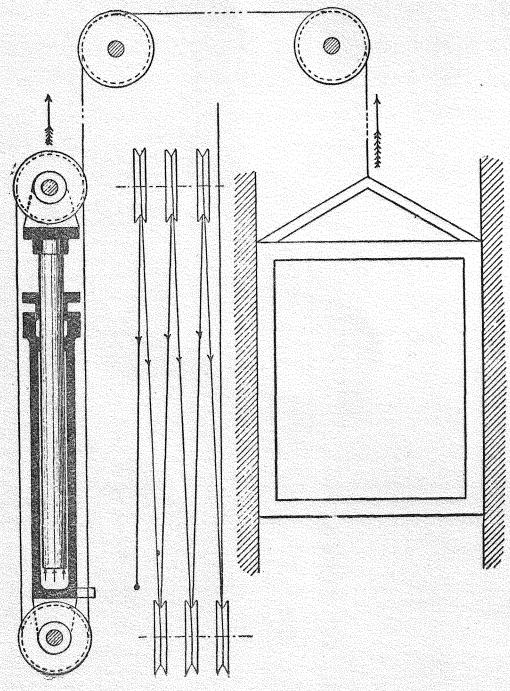
Plate XV.—HYDRAULIC LIFT.

RAM AND PULLEYS, Figs. 1, 2. The ram is of steel, $4\frac{1}{8}''$ diameter, and is provided at the top with a substantial cast-iron head to carry the three wire rope pulleys, the end being turned down to $3\frac{1}{8}''$ diameter to fit into the base of the head to which it is fixed by a $\frac{1}{2}''$ bolt. The pulleys are equal, in all respects, to those on the end of the cylinder, and the $2\frac{3}{4}''$ diameter pin about which they turn is fixed by a $\frac{5}{8}''$ set screw as shown. The oil for the lubrication of the pin passes down the $\frac{3}{8}''$ hole in the right-hand support, along the centre of the pin, and out by the three branch holes. The groove in each pulley is V shaped, rounded at the bottom to $\frac{1}{4}''$ radius, and the wire rope used for the transmission of the motion rests on the bottom.

As will be seen from the plan, Fig. 2, the horizontal flange of the head is of oval shape, and has at each end a rectangular groove, so that it may move between the two vertical guide rods, and be prevented from turning.

Admission and Exhaust Valve, Figs. 3, 4. The body of the valve is of brass, and has three oval flanges, one to the horizontal branch connected with the cylinder, and the others to the branches for the admission and exhaust of the water. The inlet for the water is $\frac{5}{8}''$ diameter, the exhaust passage, $\frac{7}{8}''$ diameter, and the passage into the cylinder, also $\frac{7}{8}''$ diameter. The ends of the two vertical spindles form the valves for the control of the water, and they may be raised or lowered by turning them in one or the other direction. In order that only a fraction of a turn of the spindle may raise the end sufficiently, the screw passing through the gland is made double-threaded. Each spindle is packed in the usual way by means of a hat leather, separated from the end of the gland by a brass washer. The leather ring of triangular section forms the packing for the flange against the cylinder. The ascent or descent of the ram is effected by the opening of one valve and the closing of the other.

Estimation of the Load Lifted. As explained on the previous page, the rope passes round all the pulleys, so that there are six portions of rope passing from the end of the ram. By this means the motion of the end of the rope to which the load is attached will be six times that of the ram, and therefore, from the principle of work, the theoretical load will be $\frac{1}{6}$ the total pressure on the end of the ram.



If p = pressure per square inch in the cylinder.
d = diameter of ram in inches.
w = theoretical load lifted.
n = number of pulleys at the end of the ram,
then, motion of load = 2n (motion of ram),

and $p \times \frac{d^2 \pi}{4} = w \times n$

Actual load = w × efficiency.

EXERCISES.

1. **Ram, Figs. 1, 2.** Draw the two given views, and add a side elevation. *Scale $\frac{1}{3}$ full size.*

2. **Admission and Exhaust Valve, Figs. 3, 4,** Draw the two given views and add a plan projected from the sectional elevation. *Scale full size.*

HYDRAULIC LIFT.

DETAILS OF RAM AND PULLEYS.

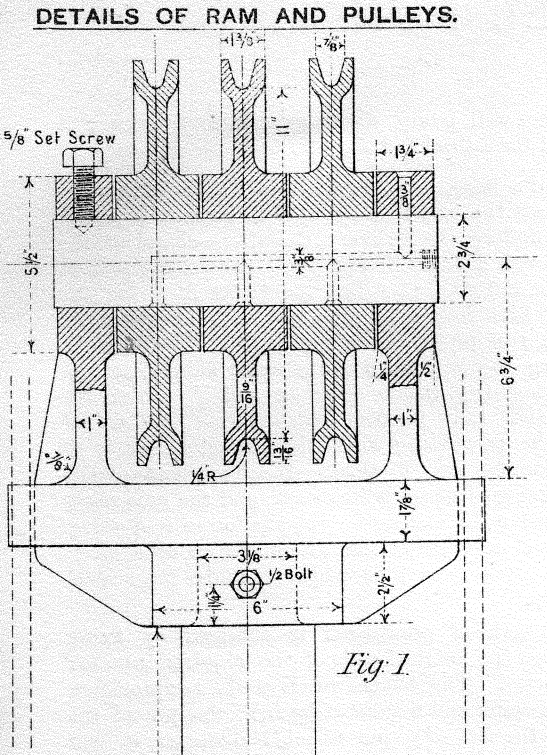


Fig. 1.

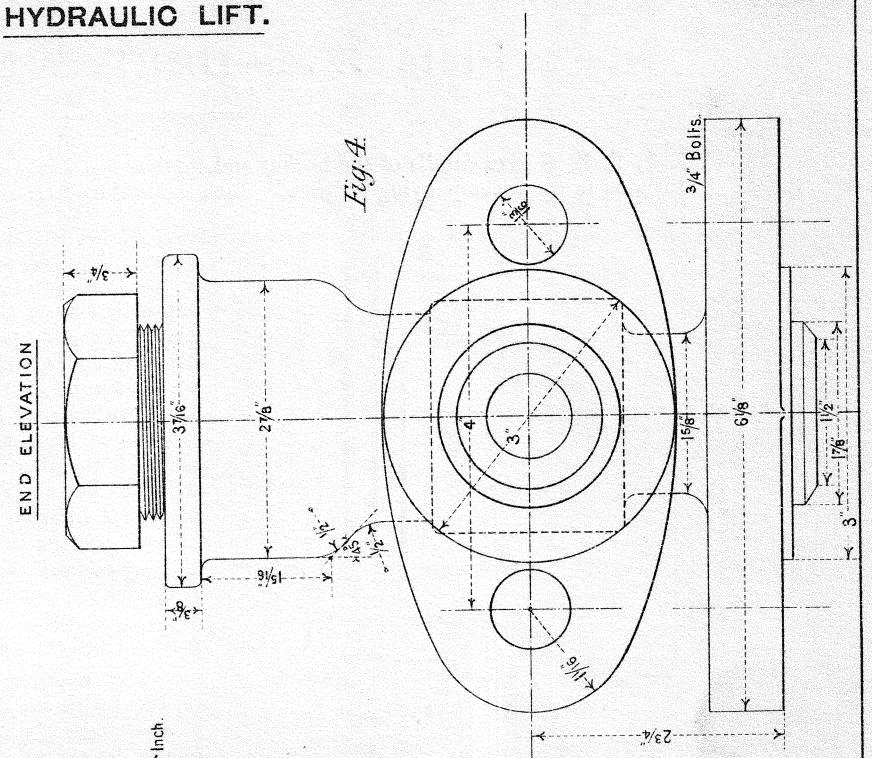
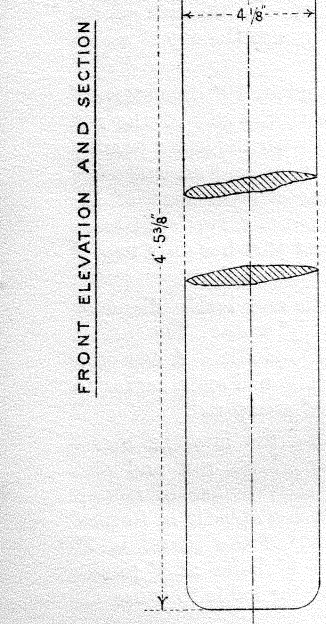


Fig. 4.



Scale 2"=1 Foot.

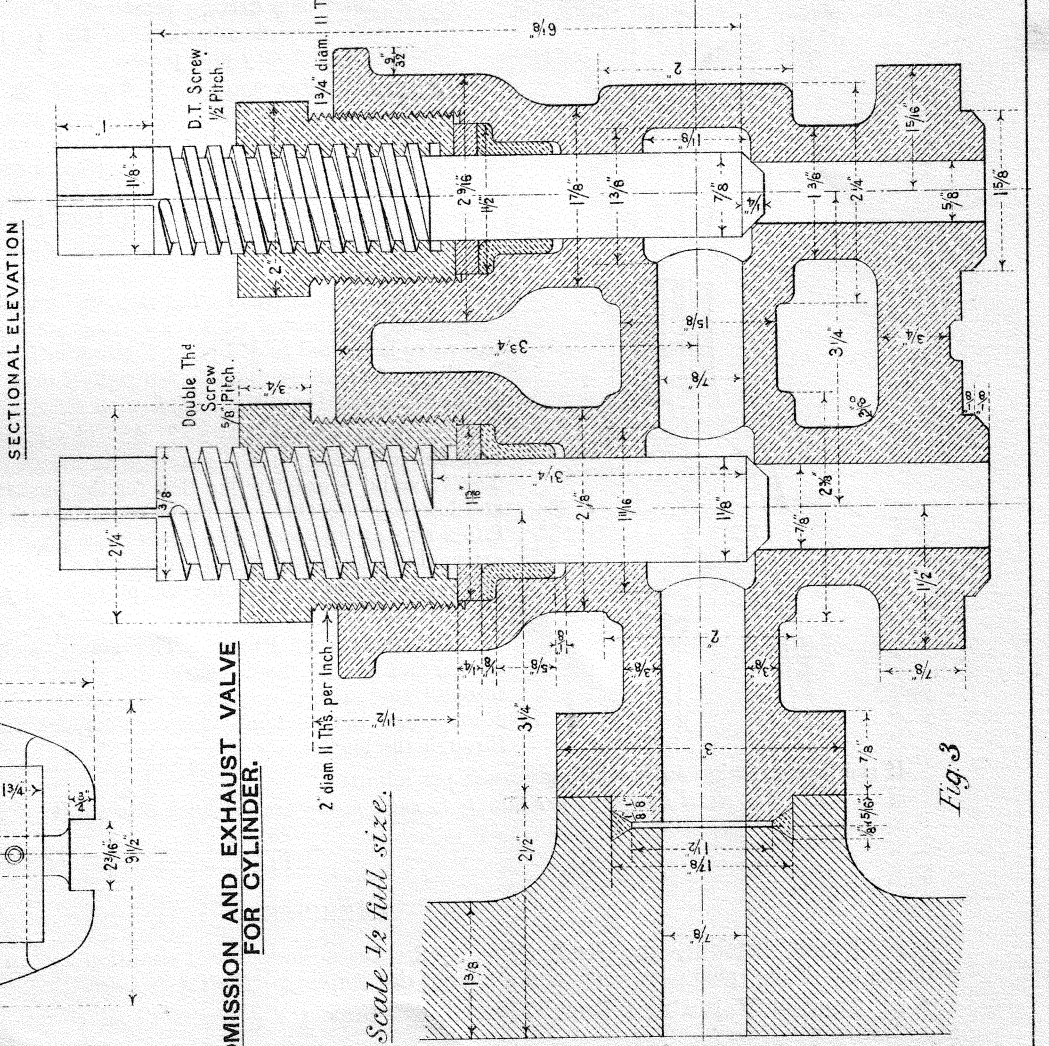

SECTIONAL ELEVATION
6 1/8"
D.T. Screw 1/2 Pitch.
1 3/4" diam. 11 Ths. per Inch.
Double Thd Screw 5/8 Pitch.
2" diam 11 Ths. per Inch
Scale 1/2 full size.

Fig. 3.

PLAN OF RAM.

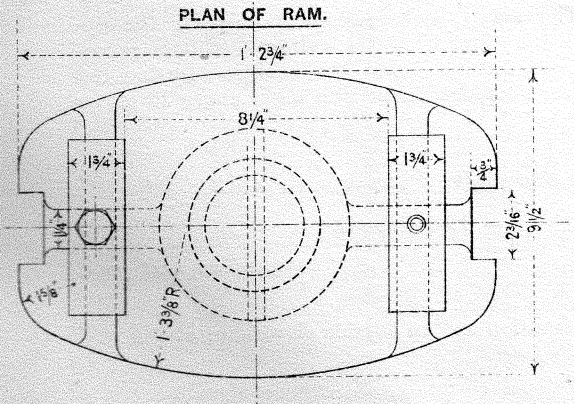


Fig. 2.

ADMISSION AND EXHAUST VALVE FOR CYLINDER.

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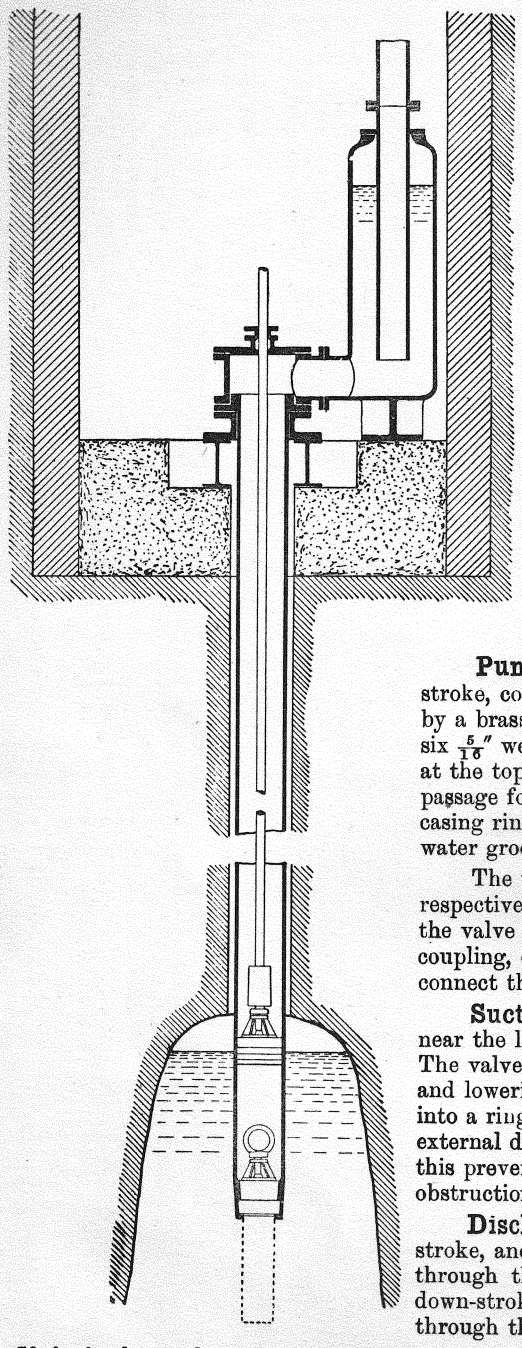
Plate XVI.—DEEP WELL PUMP.

FIGS. 1, 2, 3, 4 give details of the bucket and suction valve for a deep well pump, whose general arrangement is indicated in the accompanying diagram. Such a pump may be used for a total lift of 1,000 feet.



At the bottom of a bricked cylindrical hole, 7′ diameter × 13′ deep, and carried across the bore-hole by small I girders, is placed a short cast-iron cylinder—the delivery chamber—closed at the top with a cover through which the pump rod passes, and bolted below to a loose plate and a circular disc, the latter receiving the screwed end of the first length of pipe, and so supporting the whole weight of the rise pipes and pump barrel. To obtain a barrel sufficiently long to reach down to the water supply, several lengths of steel tubing, $10\frac{3}{8}$″ inside diameter and $\frac{7}{16}$″ thick, are screwed together; and that portion which forms the actual working barrel, or the part along which the bucket moves, is of brass, 10″ internal diameter and $\frac{5}{8}$″ thick. Near the end of the brass barrel the thickness of metal is increased, and the hole made slightly conical to receive the seating for the suction or foot valve. Immediately below, and attached to the internal flange by eight $\frac{5}{8}$″ brass studs, is the suction rose pipe which excludes large solid matter from the pump.

The required length of pump rod is obtained by fixing together with couplings the notched ends of the required number of steel rods, 2″ diameter. The bucket receives its reciprocating motion by means of a crank and a connecting rod; the pin of the former being fixed in the face of a spur wheel, 7′ diameter, in gear with the driving pinion of 1 foot diameter. To the side of the delivery chamber is fixed the air vessel, through the top of which the delivery pipe passes.

Pump Bucket and Rod, Figs. 1, 2. The bucket, 10″ diameter × 3′ stroke, consists of two brass hollow pieces connected with the end of the rod by a brass nut and pin. The boss of each is connected with the outer part by six $\frac{5}{16}$″ webs, and those of the upper piece forming the valve seat are cut away at the top to the extent of $\frac{1}{2}$″, so that they may not diminish the area of the passage for the water. The lower part of the bucket contains two split brass casing rings and a coiled piston packing, while the upper part has only two $\frac{1}{4}$″ water grooves.

The valve consists of a flat ring, $8\frac{3}{8}$″ and $3\frac{5}{8}$″ outside and inside diameter respectively, connected with the vertical portion by six $\frac{5}{16}$″ webs. The lift of the valve is limited to $\frac{5}{8}$″ by the 4″ shoulder forged on the spindle. A cast-iron coupling, of square section, driven tightly over the two notched ends, serves to connect the spindle of the bucket with the first length of pump rod.

Suction Valve, Figs. 3, 4. The conical seating fits into the barrel near the lower end, and the spindle is secured to it by a brass nut and pin. The valve lid is exactly like that for the bucket. For convenience in raising and lowering the valve during erection or examination, the spindle is formed into a ring at the top. The brass rose pipe on the end of the barrel is 7″ external diameter and 2′ long, perforated all over with $\frac{1}{2}$″ holes at $\frac{3}{4}$″ pitch: this prevents the passage into the pump of any solid matter liable to cause an obstruction.

Discharge of Pump. The pump discharges water only on the up-stroke, and during the discharge the water from the well or bore hole passes through the suction valve, and accumulates below the bucket. During the down-stroke the suction valve remains closed, and the water above it passes through the bucket.

If the bucket makes twelve lifting strokes per minute

The theoretical discharge per minute in cubic feet = area of bucket in sq. ft. × stroke in ft. × 12

$$= \frac{78{\cdot}5}{144} \times \frac{3}{1} \times \frac{12}{1} = 19{\cdot}6 \text{ cubic ft.}$$

[*Continued on next page.*

EXERCISES.

1. **Pump, Bucket, and Rod, Figs. 1, 2.** Draw the sectional elevation and an outside elevation; also a plan with the top of the spindle removed, and a plan of the coupling. *Scale $\frac{3}{8}$ full size.*

2. **Suction Valve and Rose, Figs. 3, 4.** Draw the given sectional elevation, an outside elevation and a plan. *Scale $\frac{3}{8}$ full size.*

DEEP WELL PUMP.

DETAILS OF PUMP BUCKET.

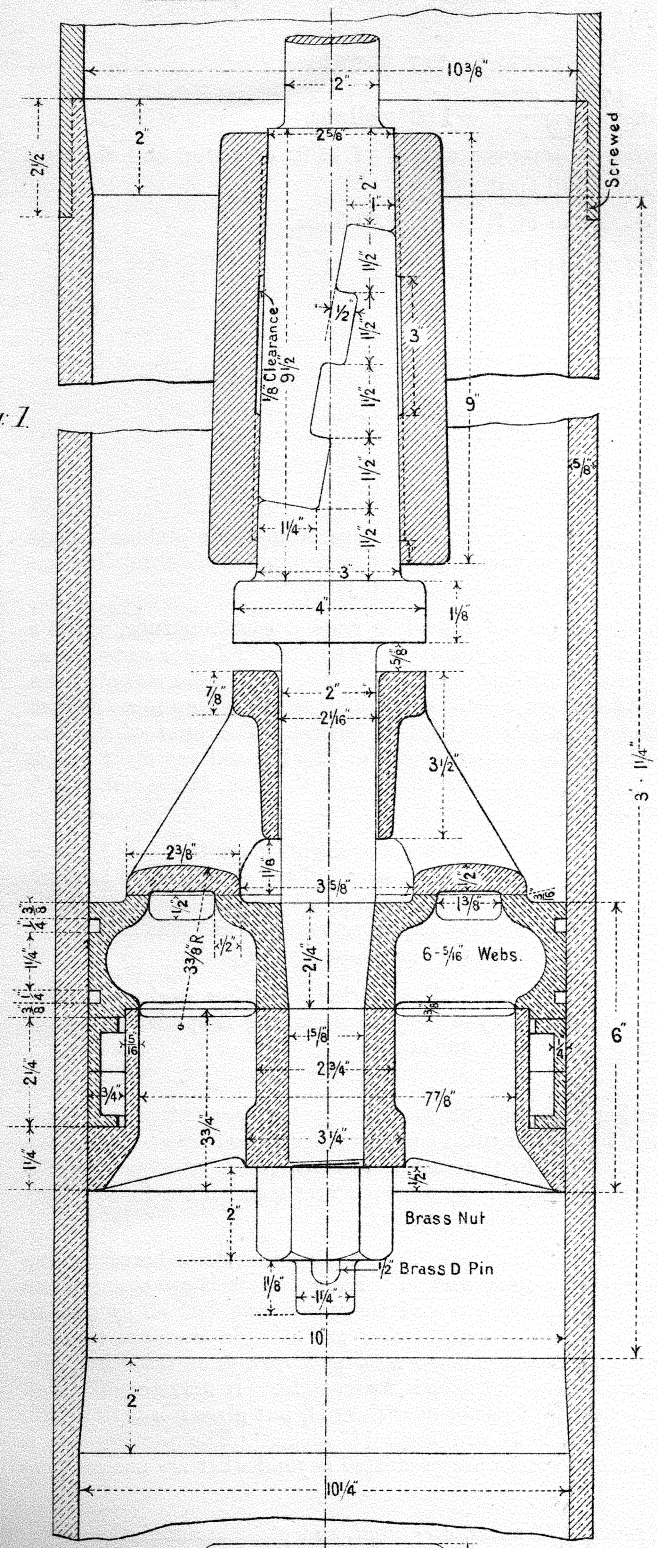


Fig. 1.

DETAILS OF SUCTION VALVE

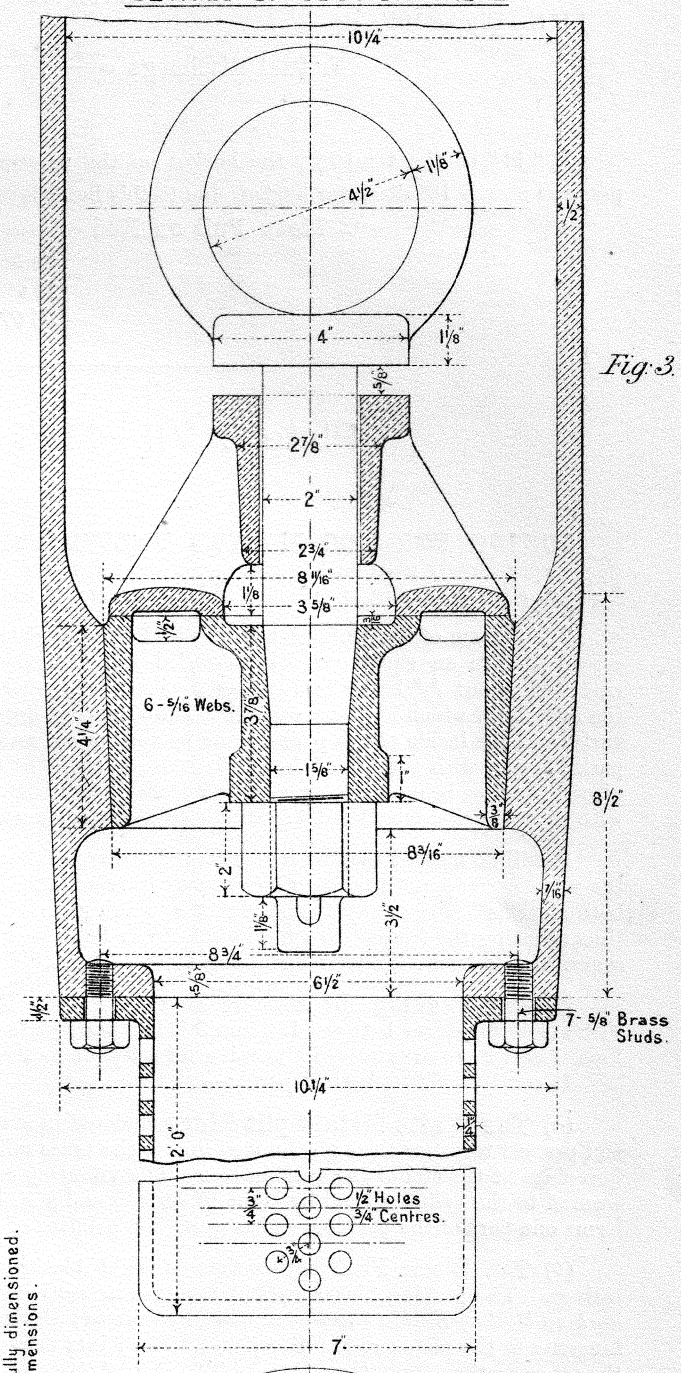


Fig. 3.

NOTE: Since the two valve lids are alike neither drawing is fully dimensioned. See Figs. 1 & 3 for dimensions.

Scale 3" = 1 Foot.

PLAN OF CAST IRON COUPLING BOX.

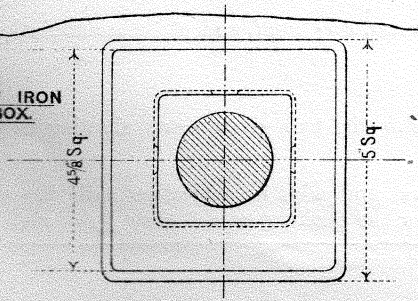


Fig. 2.

PLAN OF VALVE LID AND STOP.

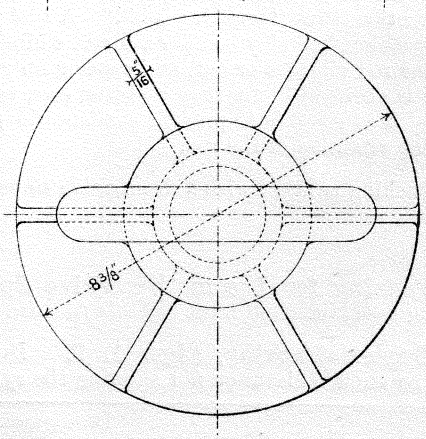


Fig. 4.

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If the slip be 10%,

$$\text{Actual discharge} = \frac{19{\cdot}6 \times 9}{10} = 17{\cdot}6 \text{ cubic ft. per minute}$$

$$= \frac{17{\cdot}6 \times 62{\cdot}5}{10} = 110 \text{ gallons.}$$

If "H" be the total lift, the bucket on the up-stroke has to overcome a head of H ft. of water, and the total pressure on the 10″ diameter bucket, due to this head, is the *mean* pull on the rod.

$$\therefore \text{Mean Pull on Rod} = \text{Area of bucket in sq. ft.} \times H \times 62{\cdot}5 \text{ lbs.}$$

$$= \frac{78{\cdot}5}{144} \times 62{\cdot}5 \times H \text{ lbs.}$$

$$= 34{\cdot}07\ H \text{ lbs.}$$

Plate XVII.—METALLIC PACKINGS.

PACKING FOR LOCOMOTIVE VALVE SPINDLE, Figs. 4, 5. This type of metallic packing is now very largely used on locomotive engines for the piston rods and valve spindles on account of its durability, and the small amount of pressure which it exerts on the rod to maintain a steam-tight joint.

The bottom of the stuffing box is fitted with a brass bush, and on the top of it rests a cast-iron tube, which is separated from an equal one above—called the *follower*—by a helical steel spring. Above the follower rests a brass ring—bored out $\frac{1}{16}$″ larger in diameter than the rod—holding three Babbitt metal split rings in a brass *vibrating cup*, the interior of which is partly conical. The vibrating cup rests against a ball ring which is pressed up to a spherical surface on the inside of the *packing case* by the spring, and thus a steam-tight joint is formed. The joint of the oval packing case, with the top of the stuffing box, is made by one complete copper ring, No. 12 wire, and two short curved pieces, the case being held down by two $\frac{3}{4}$″ studs (not shown in the plan). On the top of the case, and attached to it with two $\frac{1}{4}$″ studs, is a thin brass ring, containing some well oiled hemp.

It will be noticed that by its construction the packing may have a direct sliding movement upon the face between the vibrating cup and the ball ring, or may have a rocking motion between the ball ring and the case, or may combine both motions at once. By this device the packing never binds the rod, but follows it in all its vibrating movements, thus reducing the friction to a minimum. The Babbitt rings are the only parts requiring renewal, and it is no unusual occurrence to have locomotives running 80,000 to 100,000 miles without renewing or adjusting the packing.

Duplex Packing for Marine Engine Piston Rod, Figs. 1, 2, 3. For marine and other engines working with steam pressures between 150 and 300 lbs. per square inch, the duplex type of metallic packing is specially adapted. Figs. 1 and 2 are drawings of a packing for a $9\frac{1}{2}$″ diameter piston rod of a marine engine.

It consists of two distinct parts :—

(*a*) **The White Metal Split Rings** enclosed in a vibrating cup—similar to those in the locomotive packing—and pressed together through the medium of the brass follower, by sixteen small coiled springs placed between two cast-iron rings at the end of the stuffing box. The vibrating cup is held up by the cast-iron gland, whose circular flange is secured to the cylinder head by eight $\frac{5}{8}$″ screws, and a steam-tight joint made by a copper ring between the faces. This forms one part of the packing, and is quite independent of the other—the block packing.

(*b*) **The Block Packing** consists of eight blocks, which are held in brass rings, having pockets or horns holding springs. The packing blocks are put together in sections, four blocks to a section. Each section is composed of *two working blocks—Babbitt lined*—and *two guide blocks*; the latter are the segments of the whole ring cut off by parallel tangents to the piston rod. (See plan.) The joints between the blocks in one section are at right angles to those in the other section, thus "breaking joint." A *ball joint* on one side, and a *follower bush with springs* on the other, give the block packing free play—either a direct sliding or a rocking motion—and keep it steam tight. It works equally well whether the rod vibrates or not, and causing only very slight friction it does not wear the rod, but gives it a high polish. The whole is enclosed in a strong cast-iron *case*, bolted to the cylinder head with eight $1\frac{1}{4}$″ studs. The packing case is made as thick as possible to prevent condensation, and no clearance spaces are permitted beyond what are necessary to allow for the vibration of the rod.

The packing is fitted with a drain valve to permit of the removal of water, *core sand*, and other accumulations.

EXERCISES.

*1. **Packing for Locomotive Valve Spindle, Figs. 4, 5.** Draw the two given views, showing in the plan the packing case studs and nuts. *Scale full size.*

*2. **Duplex Packing, Figs. 1, 2.** Draw the two given views, and add, in projection with the sectional elevation, an outside elevation not showing the cylinder head, the gland, or the packing case. *Scale $\frac{3}{8}$ full size.*

* These Exercises are intended for Advanced Students.

METALLIC PACKINGS (UNITED STATES).

DUPLEX TYPE FOR MARINE ENGINE PISTON ROD.

SECTIONAL ELEVATION

Fig. 1.

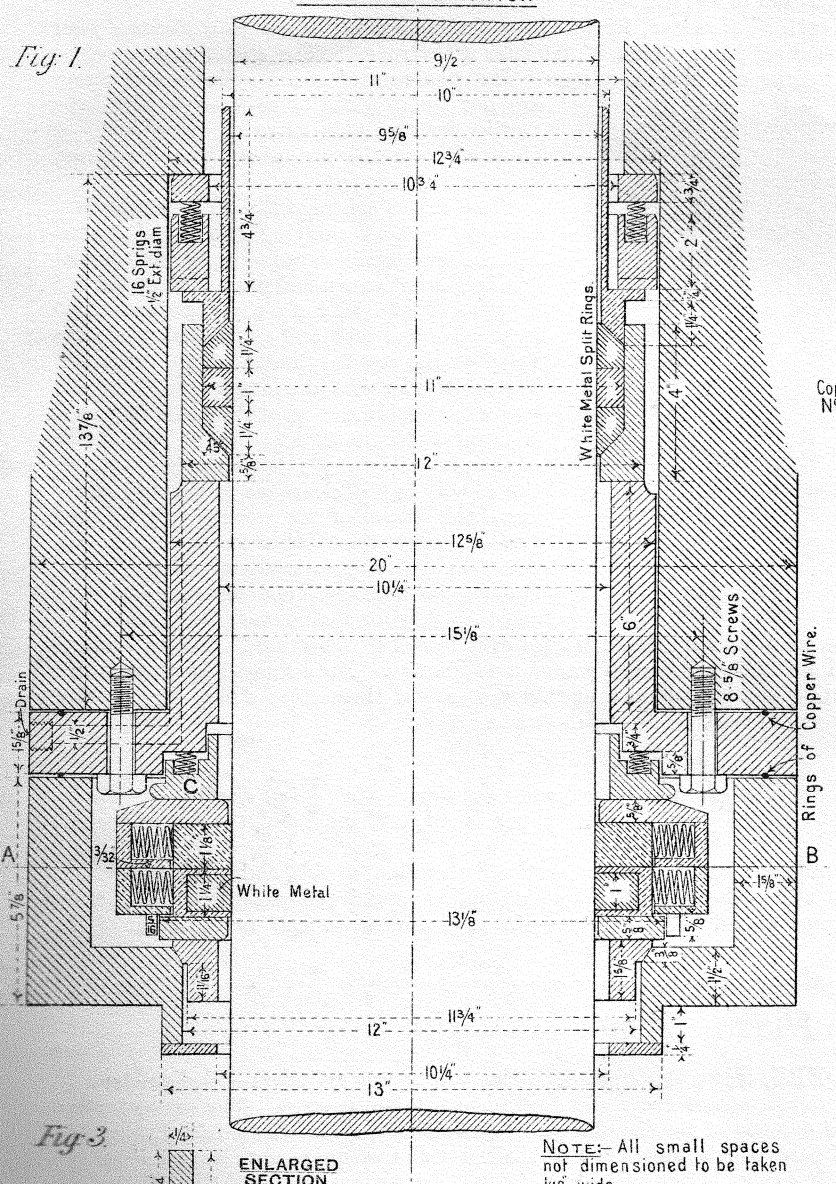
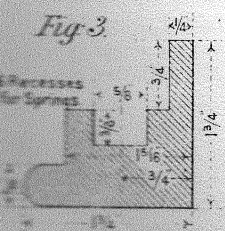


Fig. 3.



NOTE:– All small spaces not dimensioned to be taken 1/16 wide.

Scale ½ full size.

SECTIONAL PLAN AT A. B.

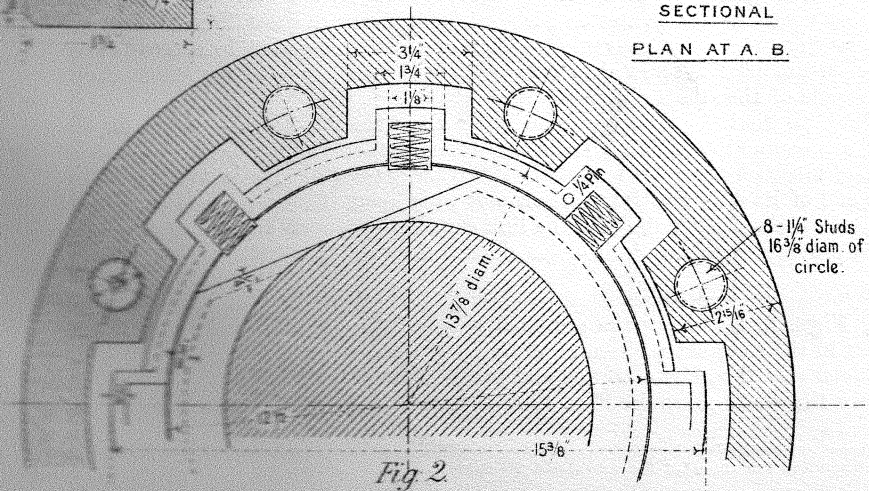
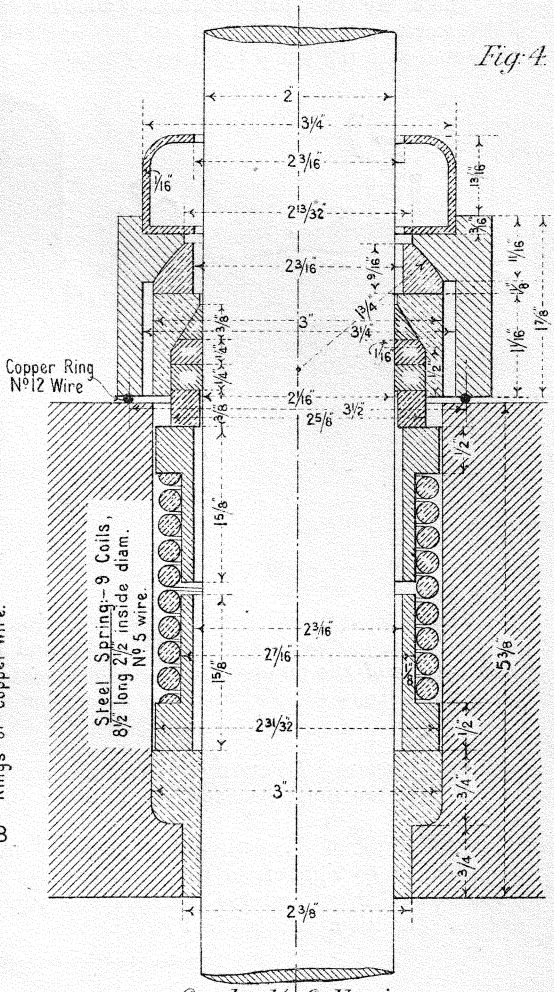


Fig. 2.

PACKING FOR LOCO. VALVE SPINDLE.

SECTIONAL ELEVATION

Fig. 4.



Scale ½ full size.

PLAN.

Fig. 5.

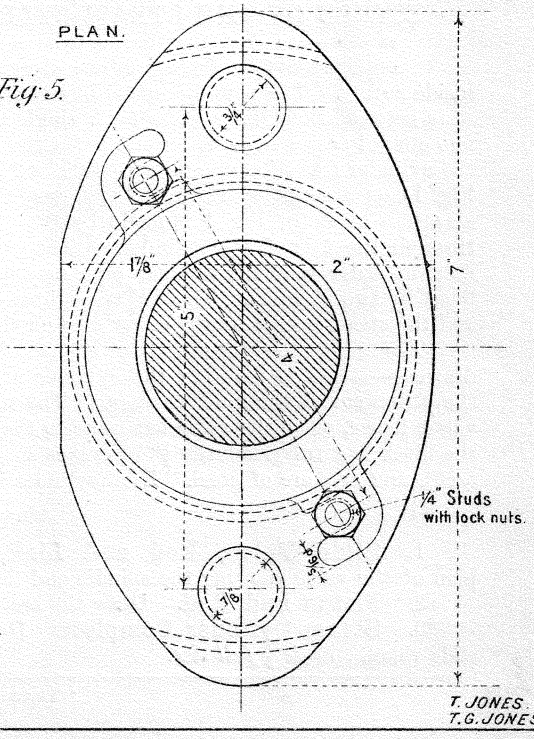


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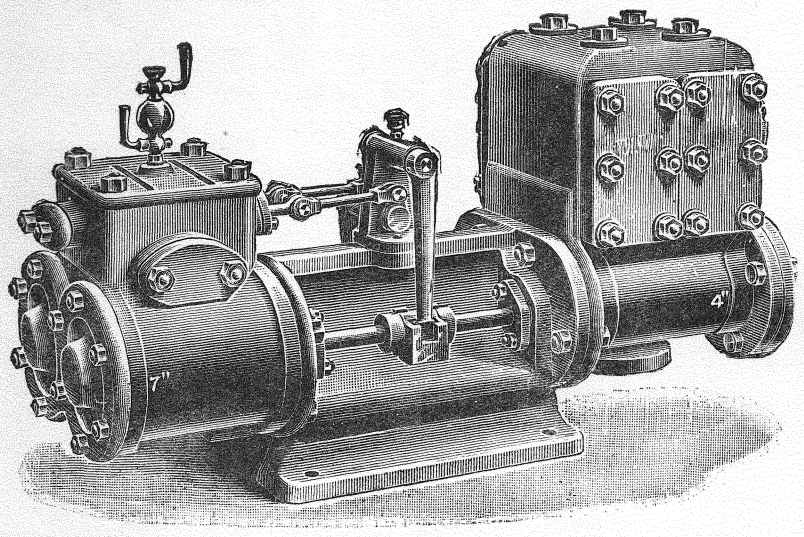
Plate XVIII.—DUPLEX STEAM PUMP.

GENERAL ARRANGEMENT. The coloured drawings and the accompanying illustration represent a duplex direct-acting steam pump suitable for boiler feed or moderate lifts.

There are two parallel steam cylinders, each 8″ diameter, formed in a single casting, bolted to a *distance piece* which carries at the other end the two double-acting pumps, each 5″ diameter × 7″ stroke. The steam piston rod is connected with the pump rod directly opposite by the cast-iron coupling.



The two sets of steam cylinder and pump are not independent of each other since the motion for the slide valve of one cylinder is obtained from the piston of the other steam cylinder.

Fixed in the centre of the *distance piece* is a cast-iron bracket carrying two pairs of steel levers; each pair is keyed to a pin and consists of a long lever, whose end fits in the piston rod coupling of one set, and a short one, connected by a valve rod link and spindle to the slide valve for the steam cylinder of the other set. The relative lengths of a long lever and the corresponding short one are 4 to 1, so that each slide valve spindle has a motion of $\frac{1}{4}$ the stroke of the piston, *i.e.*, $1\frac{3}{4}$″: but since the block on the spindle has $\frac{1}{2}$″ clearance in the top of the valve the travel of the valve is only $1\frac{1}{4}$″, and this is rendered sufficient for the steam distribution by having, for each end of the cylinder, two similar passages, one for the admission and the other for the release of the steam.

The ends of the *distance piece* form the inner covers for both the steam cylinders and the pumps. The two pumps are formed in one casting with a 4″ suction and a 4″ delivery branch common to the two. No air vessel is fitted on the delivery side of the pumps, since two double-acting pumps combined in this way give of themselves a very regular flow along the delivery pipe, without any concussion at the beginning of each stroke.

EXERCISES.

*1. **General Drawing.** Draw the two views as given in the coloured drawing. *Scale $\frac{1}{4}$ full size.*

N.B. Care must be exercised in fixing the centre-lines, since the paper is only 15″ wide, and the two views will occupy a net width of 13.″

*2. **General Drawing** (on paper of imperial size). Draw a sectional elevation, a plan and an end elevation projected to the right from the plan, and also a side elevation of the steam cylinders and pumps only—the distance piece to be omitted and the cylinders and pumps placed close together—in projection with, and to the right of the sectional elevation. *Scale* 3″ = 1 *foot.*

Plate XIX.

DETAILS OF THE STEAM CYLINDERS, Figs. 1, 2, 3, 4. The two steam cylinders—8″ diameter × 7″ stroke—are cast together, and have a common steam chest and a common exhaust passage. The covers for the outside ends are formed in one piece, and one end of the distance piece, to which the cylinders are bolted, form the inside covers. The piston is made in two equal parts which, when fixed on the rod with the square nut, leave a space $1\frac{1}{2}$″ wide between their inner edges for a single packing ring. Connecting the steam chest with each end of the cylinder are two curved passages,—the outer one for the admission of steam, and the inner one for the release—which terminate on the cylinder face in rectangular ports $\frac{5}{8}$″ × $2\frac{1}{4}$″. The passages do not enter the cylinders at the top but at one side (see Fig. 1) on account of the valve spindles being closer together than the piston rods; consequently, the sectional side elevation given in Fig. 1 is made by two planes, one through the centre of the ports up to the barrel and the other through the axis of the cylinder. The exhaust passage terminates on each side of the steam chest in a 2″ diameter hole, in order that the exhaust pipe may pass from the more convenient side: one outlet is closed by an oval cover, fixed by two $\frac{5}{8}$″ studs. The $1\frac{1}{2}$″ wrought-iron steam pipe is screwed to a flange bolted on the top of the steam chest, and the steam enters by the elbow cast on the side of the steam chest.

The slide valve has neither lap nor lead, so that for every position other than the middle one—shown in the drawing—steam is entering the cylinder at one end and exhausting from the other, but cushioning begins as soon as the piston covers the inner passage. The steel block on the valve spindle is $\frac{1}{2}$″ narrower than the gap in the top of the valve, hence, when the valve has come to the end of its stroke with the steam port fully open, it remains stationary until the block has traversed the $\frac{1}{2}$″ clearance space. The valve spindle and the link connecting it with the end of the short oscillating arm are of steel. Each cylinder is provided with two drain holes close to the flanges.

EXERCISES.

1. **Slide Valve, Rod and Link, Figs. 5, 6.** Draw the sectional side and the sectional end elevation and plan of the valve showing the spindle and link in their correct positions. *Scale $\frac{3}{4}$ full size.*

2. **Piston and Rod.** Draw the sectional elevation, end elevation and plan. *Scale full size.*

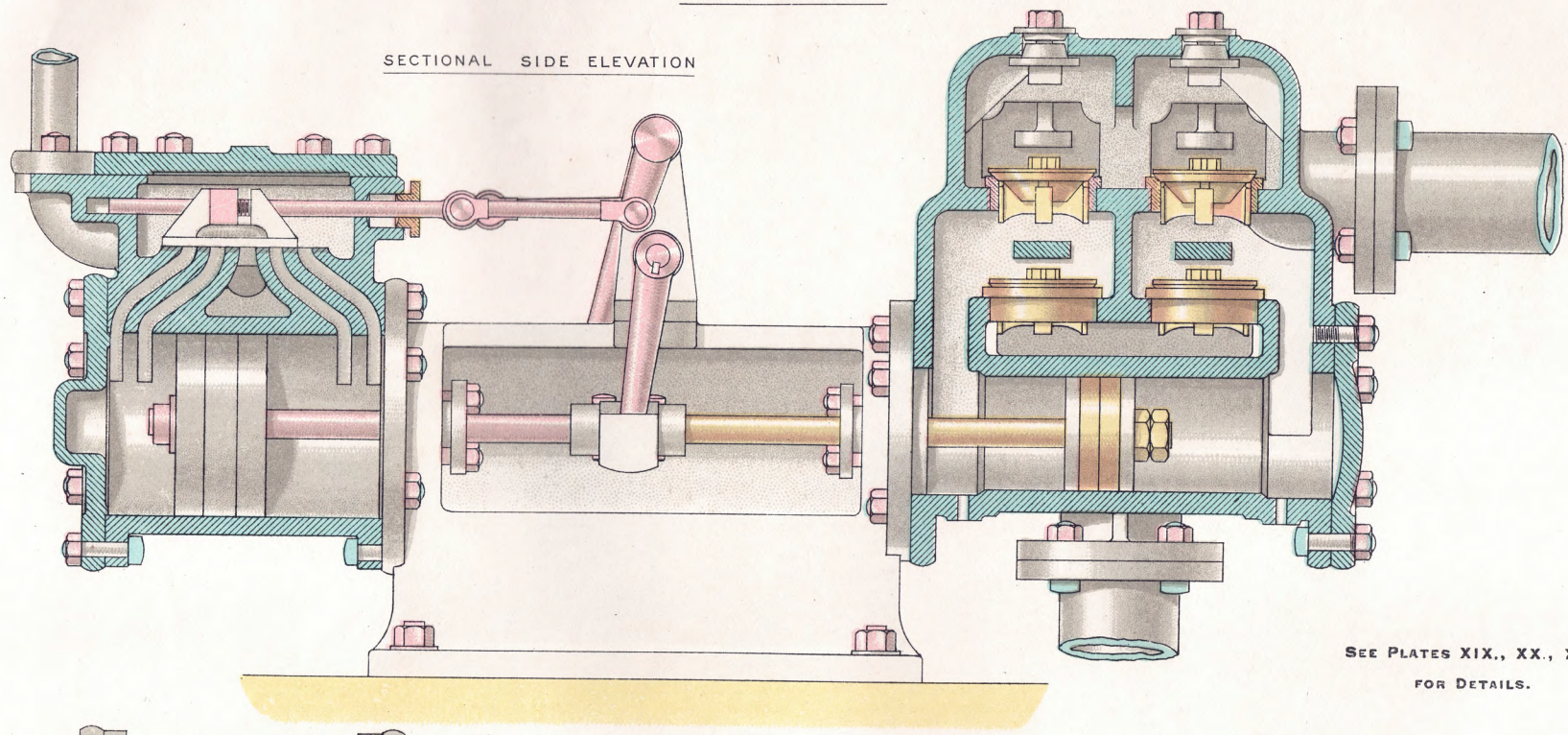
*3. **Steam Cylinder Complete.** Draw the views given in Figs. 1, 2, 3, 4, and complete the plan showing one slide valve. *Scale $\frac{1}{3}$ full size.*

* These Exercises are intended for Advanced Students.

8″ × 5″ × 7″ DUPLEX STEAM PUMP.

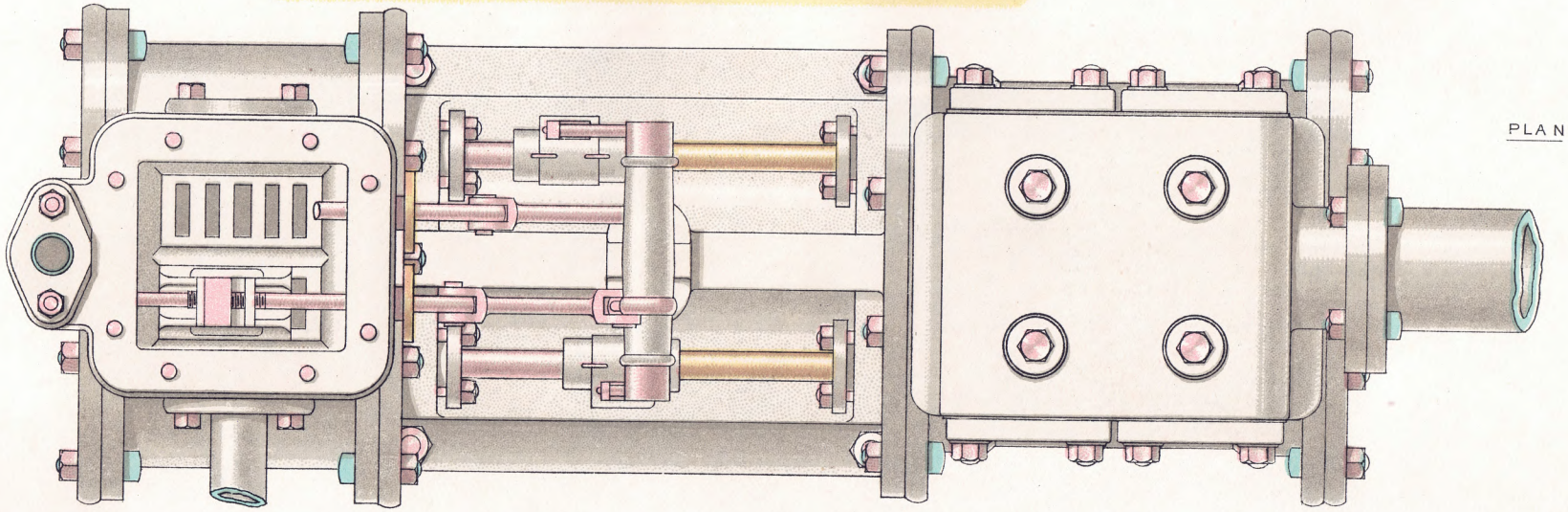
Scale 1 ½″ = 1 Foot.

SECTIONAL SIDE ELEVATION



See Plates XIX., XX., XXI. for Details.

PLAN



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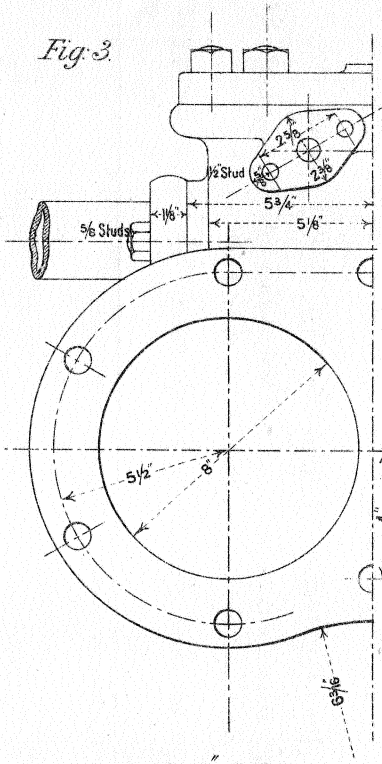
8″ × 5″ × 7″ DUPLEX STEAM PUMP.

DETAILS OF STEAM CYLINDER.

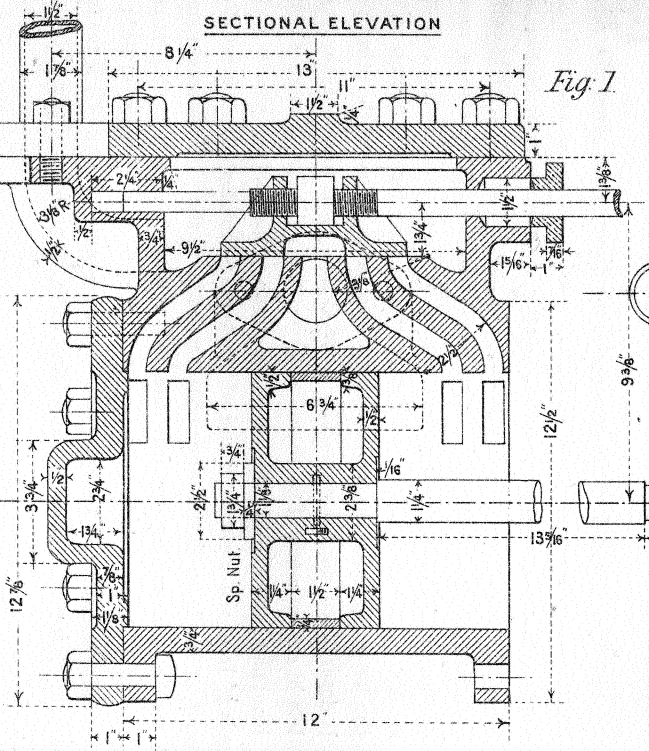
HALF END ELEVATION

Fig. 3.



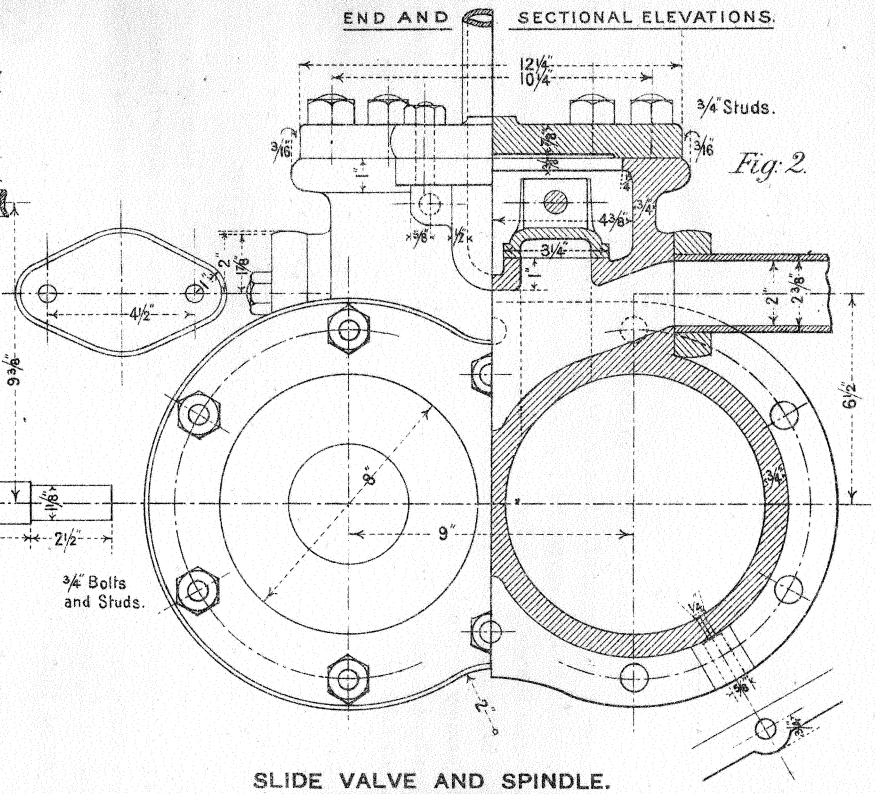
SECTIONAL ELEVATION

Fig. 1.



END AND SECTIONAL ELEVATIONS.

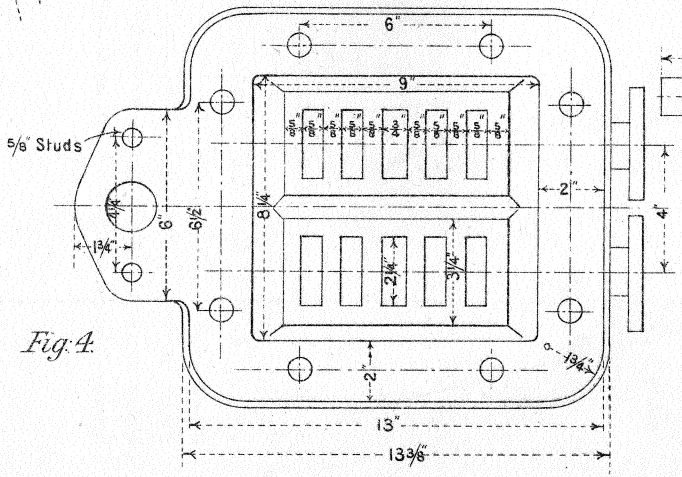
Fig. 2.



Scale 2″=1 Foot.

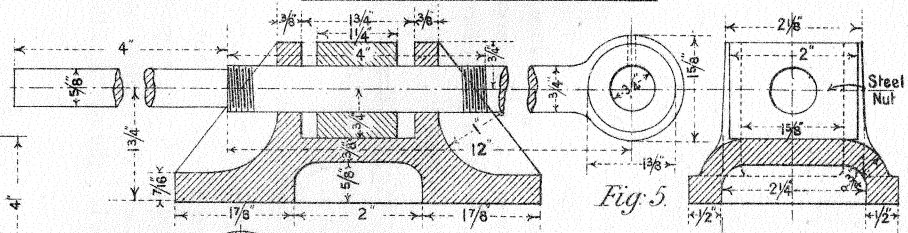
PLAN OF STEAM CHEST.

Fig. 4.



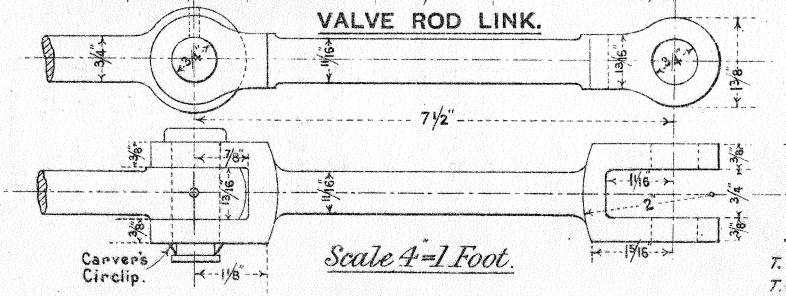
SLIDE VALVE AND SPINDLE.

Fig. 5.



VALVE ROD LINK.

Fig. 6.



Scale 4″=1 Foot.

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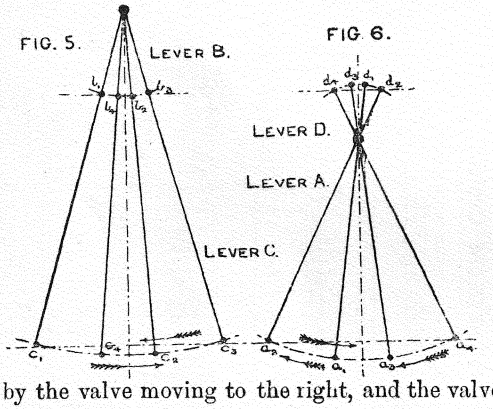
Plate XX.—DUPLEX STEAM PUMP.

DISTANCE PIECE, Figs. 1, 2. The cast-iron distance piece serves to support all the parts of the pump, and keep the steam cylinders and pump barrels in accurate alignment. It is fixed to the foundation by four $\frac{7}{8}''$ bolts, and its ends, with the brass-bushed stuffing boxes, are made to form covers for the steam cylinders and pump barrels. It will be noticed that the edges, on the end which forms the steam cylinder covers, are curved, whilst the flanges bolted to it have square edges; by this means—since the edges are not finished bright—any little inaccuracy in the coincidence of the edges is not made evident. The reverse arrangement exists at the other end. In about the centre of the length of the top edge is an enlargement which forms a face to receive the lever bracket, Fig. 3. The curved troughs below the rods are fitted with drain taps, to which access may be had by the hand-holes on the ends of the distance piece.

Coupling Box, Fig. 4. The coupling is of cast iron, and serves to connect the steel piston rod with the brass pump rod. The rod ends, turned down from $1\frac{1}{4}''$ to $1\frac{1}{8}''$, butt together in the centre of the coupling, and are secured by steel cotters $\frac{1}{4}''$ thick. A pocket is formed on one side of the coupling box to receive the end of the long lever, which, through the short lever connected with it, actuates the slide valve of the other steam cylinder.

Bracket and Levers, Fig. 3.—The cast-iron bracket is adjusted on the top of the distance piece by two steady pins, and fixed by two $\frac{5}{8}''$ bolts; it provides two bearings for the shafts of the rocking levers. The shorter levers, B, D, are formed in one piece, with their respective shafts, and the longer ones, A and C, are fixed to these shafts by keys $\frac{5}{16}''$ square; all are of steel. The relative lengths of the long and corresponding short levers are 4 to 1, so that the travel of each valve spindle is $\frac{1}{4}$ the stroke of the piston, that is $1\frac{3}{4}''$, but the travel of the valve is only $1\frac{1}{4}''$ on account of the $\frac{1}{2}''$ clearance.



In Figs. 5 and 6 of the accompanying diagram are given the relative positions of the levers when the pistons are in turn at the ends of the stroke. The successive positions of the ends a, b, c, d, of the levers A, B, C, D, respectively, are denoted by the suffixes $_{1, 2, 3, 4}$. It will be seen that while one piston, starting from the end of the stroke, moves a distance of $4\frac{1}{2}''$, the other piston moves $2\frac{1}{2}''$, and reaches the end of the stroke. For the position c_1—that is, the position for one piston to be at the left-hand end of the stroke—the position of a_1 or that of the other piston is determined as follows:—The lever C has been moving from right to left in consequence of the steam entering the cylinder through the right-hand port, and when at the end of the stroke c_1, the port has just been closed by the valve moving to the right, and the valve is $\frac{5}{8}''$ from the right-hand end of its stroke; therefore d_1 must be $\frac{5}{8}''$ from the right-hand end of its path. For the position d_1 of the lever D the other piston must be in the position corresponding with a_1, *i.e.*, $4\frac{1}{2}''$ from the beginning of the stroke, and moving towards the left. While the left-hand port of the first cylinder is being opened c moves from c_1 to c_2, a distance of $4\frac{1}{2}''$, and a moves from a_1 to a_2, a distance of $2\frac{1}{2}''$; but whilst the same port is being closed, and the first piston completes the stroke, a moves from a_2 to a_3, $4\frac{1}{2}''$, since in the latter movement the point a moves $2''$ before the point d begins to affect the valve on account of the $\frac{1}{2}''$ clearance between the valve and the block on the spindle.

EXERCISES.

*1. **Distance Piece, Figs. 1, 2.** Draw the two given views and add a plan. *Scale $\frac{3}{8}$ full size.*

2. **Bracket and Levers, Fig. 3.** Draw the two given views, and add another side elevation to the left showing the levers C and D. Add also a plan. Show the full length of every lever. *Scale $\frac{3}{4}$ full size.*

3. **Coupling Box, Fig. 4.** Draw the three given views, and add an end elevation to the left of the front elevation. *Scale full size.*

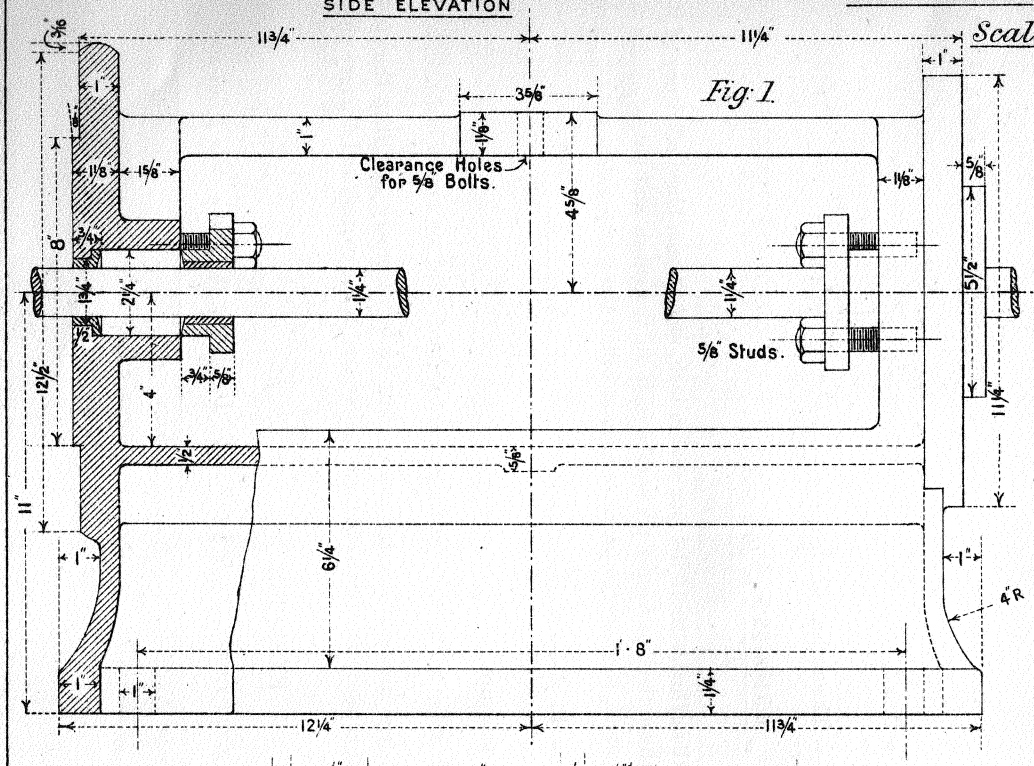
* This Exercise is intended for Advanced Students.

8" × 5" × 7" DUPLEX STEAM PUMP.

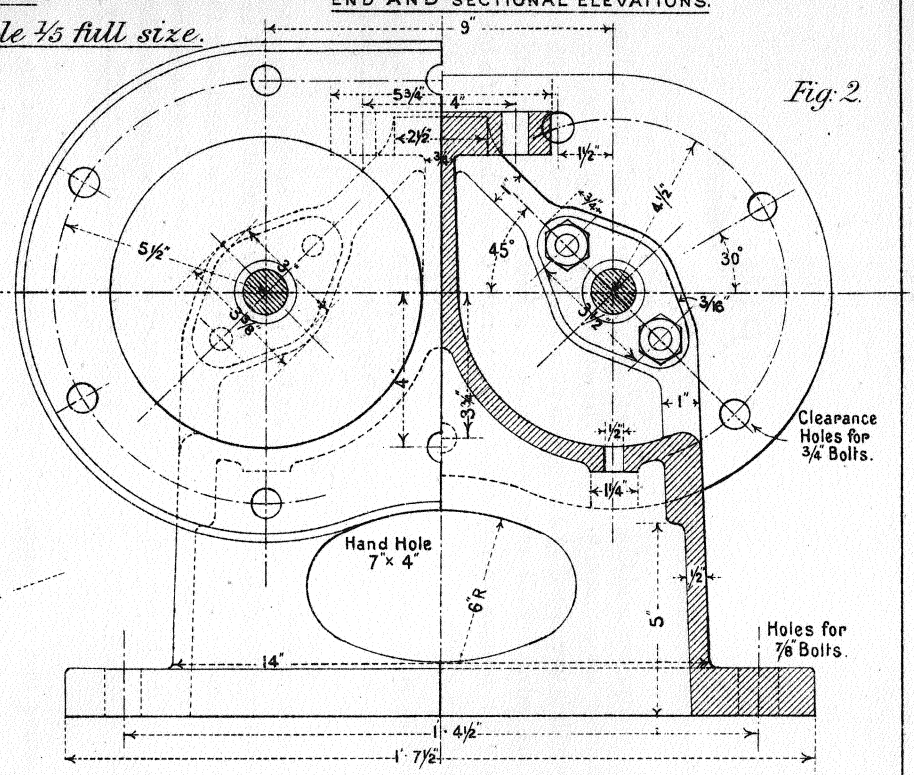
DISTANCE PIECE.

Scale ⅓ full size.

SIDE ELEVATION

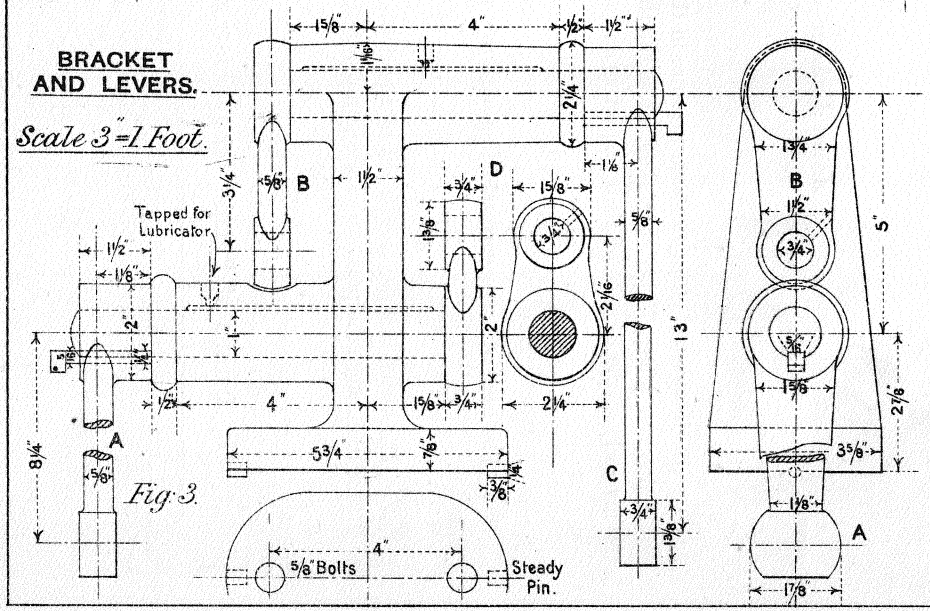


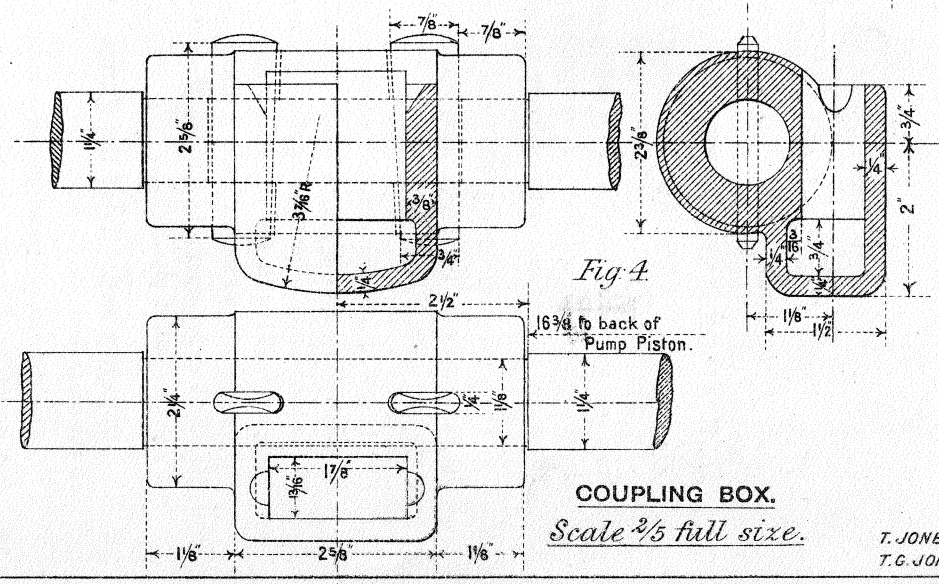
END AND SECTIONAL ELEVATIONS.



BRACKET AND LEVERS.

Scale 3" = 1 Foot.





COUPLING BOX.

Scale ⅔ full size.

T. JONES.
T.G. JONES

Plate XXI.—DUPLEX STEAM PUMP.

DETAILS OF THE PUMPS. The two pumps are made in one casting and bolted to one end of the distance piece. The suction and the delivery chamber are common to both. The suction branch is placed between the two barrels and opens out into a space which is terminated by a horizontal plate, above the barrel, fitted with four brass suction valves (see Fig. 5 for details of the valve). Each valve opens into a separate compartment, which is closed at the top by a delivery valve opening into the common delivery chamber, and connected with one end of a barrel. There are two suction and two delivery valves to each pump.

The piston is fitted with two brass split packing rings and is fixed to the brass rod by two nuts. On each side of the pump body are two covers, each providing access to one suction and one delivery valve, and formed with internally projecting arms to limit the lift of the valves.

It will be sufficient here to describe the action of one of the pumps: During the inward stroke of the piston—that is, from left to right in Fig. 1—water passes from the suction chamber into the space connected with the left-hand end of the barrel, and follows the moving piston; at the same time the water in front of the piston is discharged into the space connected with the right-hand end of the barrel and through the delivery valve into the delivery chamber. During the outward stroke, water is discharged into the delivery chamber from the back of the piston, and drawn into the barrel at the other side through the right-hand suction valve. The water passes from the delivery chamber by a 4″ diameter outlet pipe.

Capacity and Lift of the Pump. Assume that the pumps make 50 strokes per minute, and that the slip is 15 per cent, then

The theoretical discharge per minute for the two pumps = 2 × area of pump piston in square feet × stroke in feet × number of strokes per minute

$$= 2 \times \frac{19{\cdot}6}{144} \times \frac{7}{12} \times \frac{50}{1} = 7{\cdot}7 \text{ cubic feet.}$$

$$\textit{Actual discharge} = \text{Theoretical discharge} \times \frac{85}{100} = 6{\cdot}54 \text{ cubic feet}$$

$$= \frac{6{\cdot}54 \times 62{\cdot}5}{10} = \textit{40·8 gallons.}$$

If the average effective steam pressure in the cylinder be 40 lbs. per square inch, and the combined efficiency of the engine and pump 75 per cent, then, since the theoretical pressures per square inch on the steam and pump pistons are inversely as the squares of their respective diameters, the average pressure against which the pump piston works

$$= 40 \times \frac{8^2}{5^2} \times \frac{75}{100} \text{lbs.} = 76{\cdot}8 \text{ lbs. per square inch.}$$

The head of water corresponding with this pressure

$= 76{\cdot}8 \times 2{\cdot}3 = 176{\cdot}6$ ft. (a column of water 2·3 ft. high produces a pressure of 1 lb. per square inch).

The actual lift, *i.e.*, the height of the discharge above the water supply, will be considerably less than the above dimension, since the pressure on the pump piston is partly due to the frictional resistance in the suction and delivery pipes.

EXERCISE.

*1. **Details of Pump.** Draw the four given views. *Scale $\frac{3}{8}$ full size.* Detail the valve to a *scale $\frac{3}{4}$ full size.*

* This Exercise is intended for Advanced Students.

8" × 5" × 7" DUPLEX STEAM PUMP.

DETAILS OF PUMP.

LONGITUDINAL SECTION AT L. M.

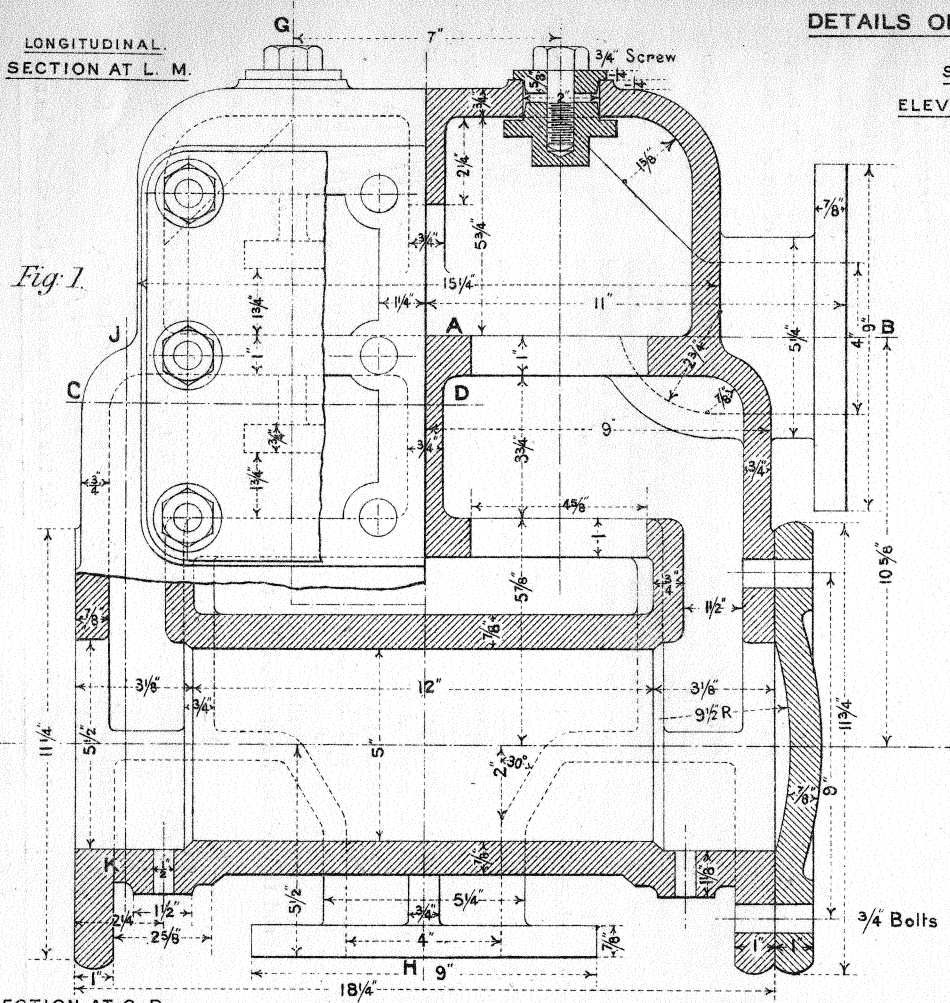


Fig. 1.

SECTIONAL ELEVATION AT C. H

END ELEVATION AND SECTION AT J. K.

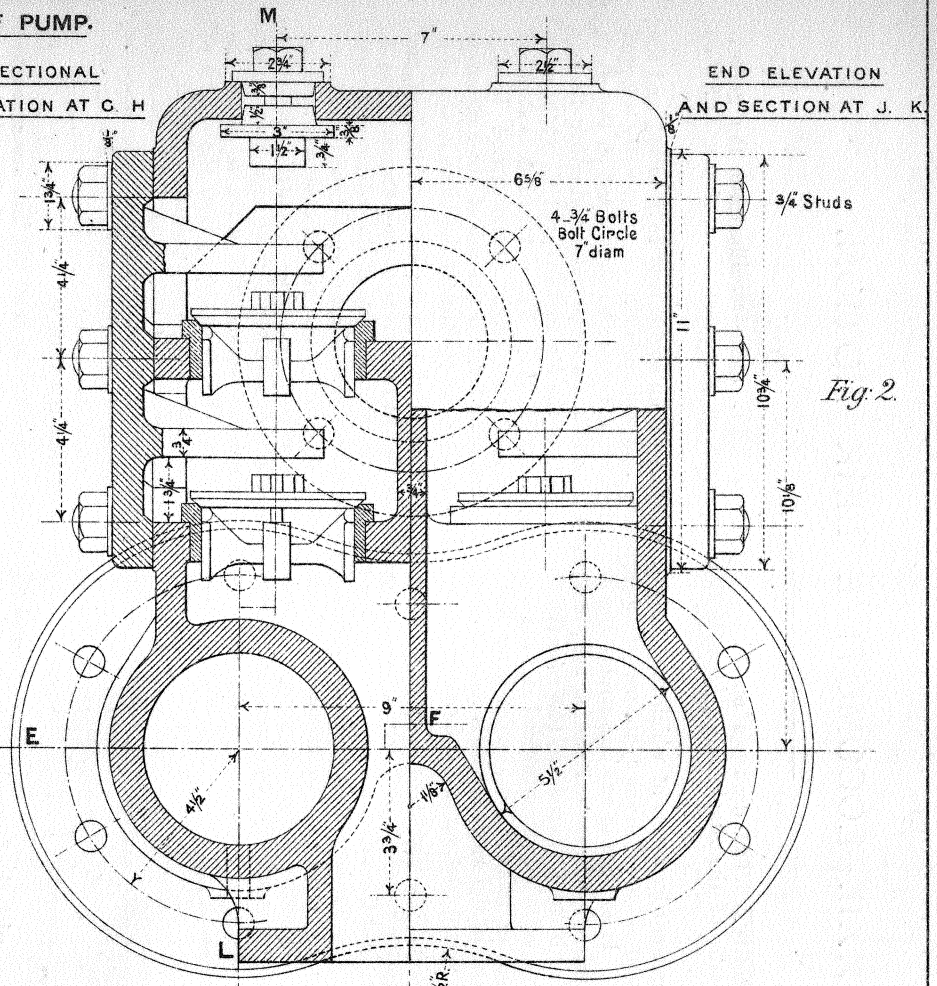


Fig. 2.

SECTION AT C. D.

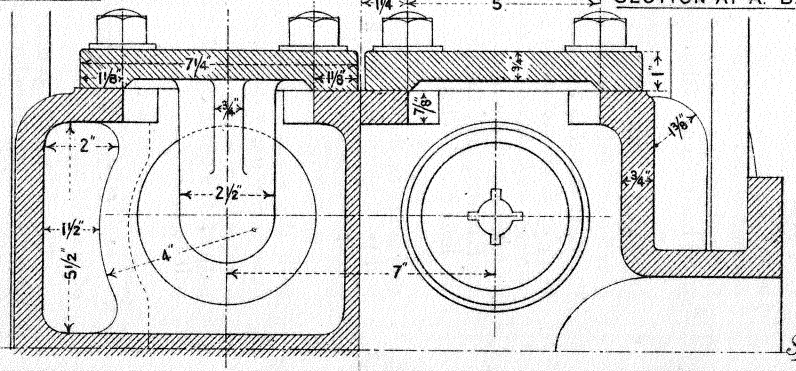


Fig. 3.

SECTION AT A. B.

SECTION AT E. F.

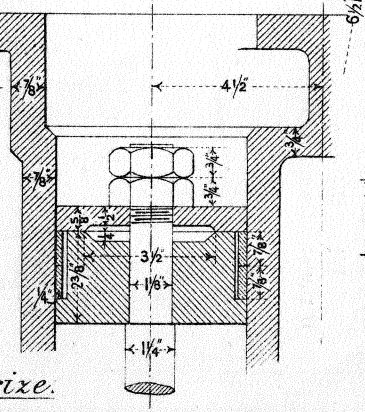

⅞"
4½"
⅜"
⅞"
¾"
¾"
⅜"
⅜"
⅜

Plate XXII.—LOCOMOTIVE LINK MOTION.

GENERAL ARRANGEMENT. The drawings on Plates XXII. to XXV. inclusive, illustrate the general arrangement and the details of the Stephenson's Link Motion, as fitted on the locomotives of the Taff Vale Railway.

A link motion is an arrangement by means of which the direction of running of an engine may be reversed, and the power varied by altering the point of cut-off in the cylinders. This particular link motion is almost universally adopted in this country for locomotives. It consists of two eccentrics—the forward and backward eccentrics—fixed on the crank axle, and connected by eccentric rods to a curved slotted link, in the slot of which is a block connected either directly with the slide-valve spindle or with the valve rod; in this case the block is fixed to the forked valve rod C, whose ends are respectively attached to the valve spindle crosshead and the suspension links B_1, B_2. The slotted link is attached at its lower end to the suspension links A_1, A_2, which hang from the arms of the weight shaft carried by the motion plate. The reversing arm of the weight shaft is connected with the reversing lever in the cab of the locomotive by a long rod so that it may be moved backwards and forwards by the driver to alter the position of the block in the link.

When the reversing arm is vertical, that is, in the position of "mid gear," the block is in the centre of the link, and if the shaft were rotated, the centre-line of the link would have a motion indicated in the accompanying diagram, Fig. 1, and the valve, a travel equal to the minimum horizontal width of the envelope formed by the several positions of the link. If the valve rod were connected directly with one eccentric rod the steam distribution would be entirely due to one eccentric, and the direction of running would be determined by the position of the eccentric relative to the crank; but by connecting the two eccentric rods with the slotted link, from which the slide valve receives its motion, the valve is under the control of both eccentrics. When the block is in the centre of the link it is controlled equally by both eccentrics, that is, the engine tends to run in one direction as much as in the other, and consequently does not run at all. If, however, the block be brought into this position whilst the engine is running, the travel of the valve on each side of its middle position will be equal to the steam lap plus the lead.

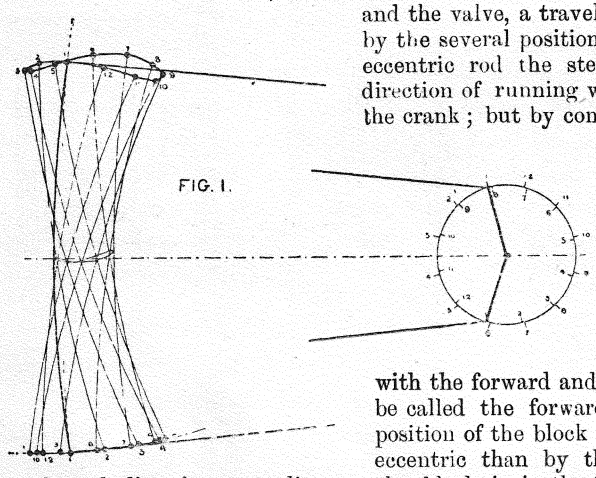


FIG. 1.

Since the upper and lower ends of the link are connected with the forward and backward eccentrics respectively, the upper half of the link may be called the forward half, and the lower half the backward half; because, for any position of the block other than the middle one, the block is controlled more by one eccentric than by the other, and consequently the engine runs in the forward or backward direction according as the block is in the forward or backward half of the link; and the greater its distance from the centre, the greater is the travel of the valve and the later the cut-off. With this gear the *lead* varies with the position of the block, being a maximum for the middle position, and a minimum for either extreme position. By moving the end of the reversing arm $7\frac{1}{4}''$ to the left, or $9\frac{3}{8}''$ to the right, the block is brought to one end of the slot, and the valve has then a maximum travel.

By accurately drawing the positions of the centre line of the link for a number of equidistant positions of the crank, the travel of the valve for any position of the block may be determined. From drawings for "mid gear" and "full forward gear," such as Figs. 1 and 2, it will be found that, for the former position, the valve travel is $2\frac{3}{4}''$, making the lead $\frac{3}{8}''$, and for the latter position the travel is $3\frac{15}{16}''$, with a lead of $\frac{3}{16}''$. A characteristic of the Stephenson's Link Motion with open eccentric rods is that the *lead increases with the rate of expansion.* That the lead decreases as the link is moved up or down from its middle position may be made evident by reference to Fig. 1. With the crank on the "out" dead centre, and the block in the middle of the link, the right-hand steam port would be open by the lead $\frac{3}{8}''$. When the link is moved its upper and lower ends must move along curves with their centres at the centres of the forward and backward eccentrics respectively, and since both curves are as shown in the diagram, the link must be moved bodily to the right, and hence the lead will be diminished. By keeping the throw of the eccentrics small, the slotted link short, and the eccentric rods long, the lead disturbance may be reduced to a minimum.

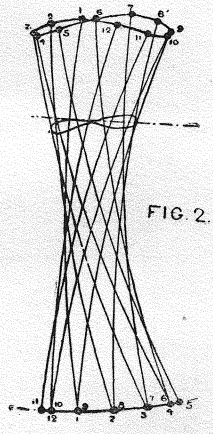


FIG. 2.

For all positions of the link its lower end moves in a circular path on account of its connection with the suspension links, A_1, A_2, but the upper end has a looped path, so also, to some slight extent, has every position of the link to which the block can be brought, and hence there will always be a slight "slotting" or rubbing of the link upon the block. On account of the circular path of the outer end of the valve rod the rubbing, suggested by the vertical height of the loop, will be modified.

[*Continued on next page.*

EXERCISES.

*1. **General Arrangement.** Draw the two given views, *scale* $1\frac{1}{2}'' = 1$ *foot*, or to a *scale* $2'' = 1$ *foot* for a sheet of imperial size.

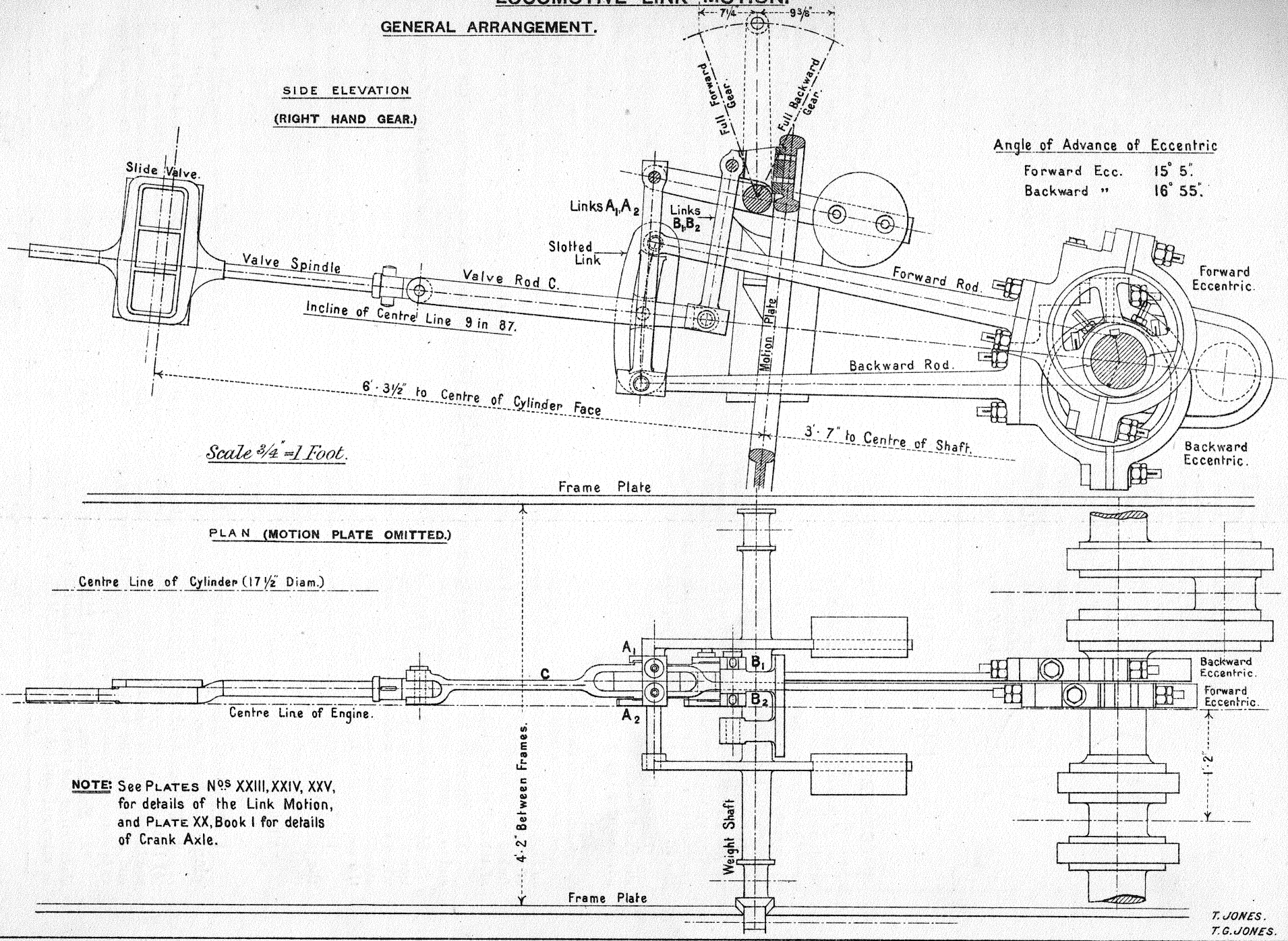
*2. **Line Diagram.** Draw two line diagrams of the gear, one for "mid gear," and the other for "full forward gear," and determine for each, the motion of the link and the travel of the valve. *Scale* $3'' = 1$ *foot.*

For convenience in drawing the many positions of the link, a template for the curvature of the link should be made.

* These Exercises are intended for Advanced Students.

LOCOMOTIVE LINK MOTION.

GENERAL ARRANGEMENT.



NOTE: See PLATES Nos XXIII, XXIV, XXV, for details of the Link Motion, and PLATE XX, Book I for details of Crank Axle.

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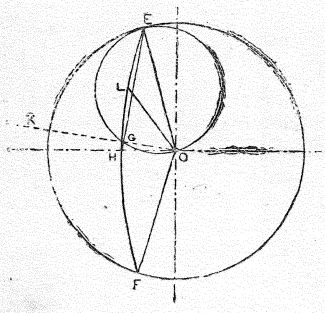
Plate XXII.—*Continued.*



For practical purposes the valve motion and steam distribution for any position of the link may be determined by the following approximate method: Let O E and O F on accompanying diagram be the forward and backward eccentrics respectively; on O E draw the valve circle cutting the line O K, which is drawn from the end of the link to the centre of the shaft, in the point G; produce the line E G to intersect the centre-line in H; through the three points E, H, F, draw an arc; this arc is called the **characteristic line** of the gear. For any position of the block in the link find a point L on the curve E H F, such that its distances from the points E and F bear the same ratio as the distances of the block from the ends of the link; then O L represents the eccentricity and position of a single eccentric which would give to the valve a motion almost identical with that of the actual motion for the particular position of the block. O L is called the **virtual or equivalent eccentric**, and from it the positions of the crank at *admission*, *cut-off*, *release*, and *compression* may be determined by Zeuner's method.

Plate XXIII.—LOCOMOTIVE LINK MOTION.

ECCENTRIC SHEAVE AND STRAPS, Figs. 1, 2, 3. The sheave is made of cast iron, in two parts, which are held together by two $1\frac{1}{8}''$ wrought-iron studs fitted with steel cotters, $1\frac{1}{8}'' \times \frac{5}{16}''$; the studs are fixed by $\frac{1}{4}''$ pins driven across them. Each sheave is fixed on the shaft by a sunk key, $1\frac{1}{8}'' \times \frac{13}{16}''$, and two steel $\frac{7}{8}''$ screws fitted with lock nuts. The sheave is 16″ diameter and $2\frac{7}{8}''$ wide; the edges are turned down $\frac{1}{4}''$, so as to leave a projection of rectangular section round the rim which fits into a corresponding recess in the brass liner of the straps, and so prevents any side motion between the sheave and the straps. The hole through which the shaft passes is bored 7″ diameter, and is $3\frac{1}{8}''$ from the centre of the sheave.

The straps are of wrought iron, held together by two wrought-iron bolts with lock nuts and split steel cotters. They are fitted with a brass liner in which the sheave moves, and the two portions of it are prevented from turning by the brass making-up pieces between the faces. The strap to which the eccentric rod is attached by two $1\frac{1}{4}''$ wrought-iron studs is provided with an oil cup for the lubricating of the rubbing surface of the sheave. The feeding hole in the brass cap of the oil cup is closed by a brass button, held in position by a light spring.

The angle of advance of the forward eccentric is 15° – 5′, that is to say, the centre line through the centres of the shaft and the sheave must lead the crank in the direction of forward running by an angle of 90″ + 15° – 5′. The angle of advance of the backward eccentric is 16° – 55′.

Eccentric Rods, Figs. 6, 7. The eccentric rods are made of wrought iron, and each is formed with a forked end for attachment to the slotted link, and a T end which is secured to the eccentric strap by two $1\frac{1}{4}''$ wrought-iron studs with lock nuts and split cotters. The forward and backward rods are alike in dimensions, but are of opposite hands: those shown in Figs. 6 and 7 are for the right-hand engine. The rods are of rectangular section—slightly rounded on the narrow edges—of constant width $\frac{7}{8}''$, and varying in depth from $3\frac{1}{2}''$ at the eccentric end to 2″ at the forked end. On the two sides of the forked end of the backward rod are placed the suspension links, A_1, A_2, which are held by the pin used for the connection of the rod with the link.

The Effective Length of the Eccentric Rod is 4′ – 10″ (being the distance from the centre of the forked end to the centre of the sheave).

Slotted Link and Block, Figs. 4, 5. The link is of the single bar type and is made from a slab of wrought iron $2\frac{1}{4}''$ thick. The curved slot has a mean radius of 4′ – 10″—the effective length of the eccentric rod—and the ends to which the rods are attached by $1\frac{1}{2}''$ wrought-iron case-hardened pins, are 1′ – $5\frac{5}{8}''$ apart. On account of the rods being attached at the top and bottom instead of at the side, the block cannot be brought opposite to either rod, and consequently the eccentric must be much larger than that corresponding with the maximum travel of the valve.

The **Block** fitting in the slot is of wrought iron and formed with an oil cup at the top, which affords lubrication to the pin of the valve rod, and the rubbing faces of the slot. It cannot be adjusted for wear, and so when it becomes a little slack there will be a vibration during the working of the gear.

All the working parts are case-hardened.

EXERCISES.

1. **Eccentric Sheave and Straps, Figs. 1, 2, 3.** Draw the side and the end elevation as given, and add a **plan** *Scale* $\frac{3}{8}$ *full size.* Detail the oil cup as shown in Fig. 3 to a *scale* $\frac{3}{4}$ *full size.*

2. **Slotted Link and Eccentric Rods.** (*a*) Draw the two given views of the slotted link, and add a plan. (*b*) Draw the side elevation of the eccentric rod, and separate plans of the forward and backward rods (not as in Fig. 7, the backward rod in dotted lines), also add an end elevation of the forward rod to the right of the side elevation, and an end elevation of the backward rod projected from the plan. *Scale* $\frac{3}{8}$ *full size. The curves of large radius will have to be drawn with beam compasses.*

*3. **Eccentrics, Rods, and Link.** Draw the side elevation, plan and end elevation (to the right of the side elevation) of the two eccentrics, rods and link in the positions given on Plate XXII. Do not show the suspension links or valve rod and take the centre-line of the engine horizontal. *Scale* 3″ = 1 *foot.*

* This Exercise is intended for Advanced Students.

DETAILS OF LOCOMOTIVE LINK MOTION

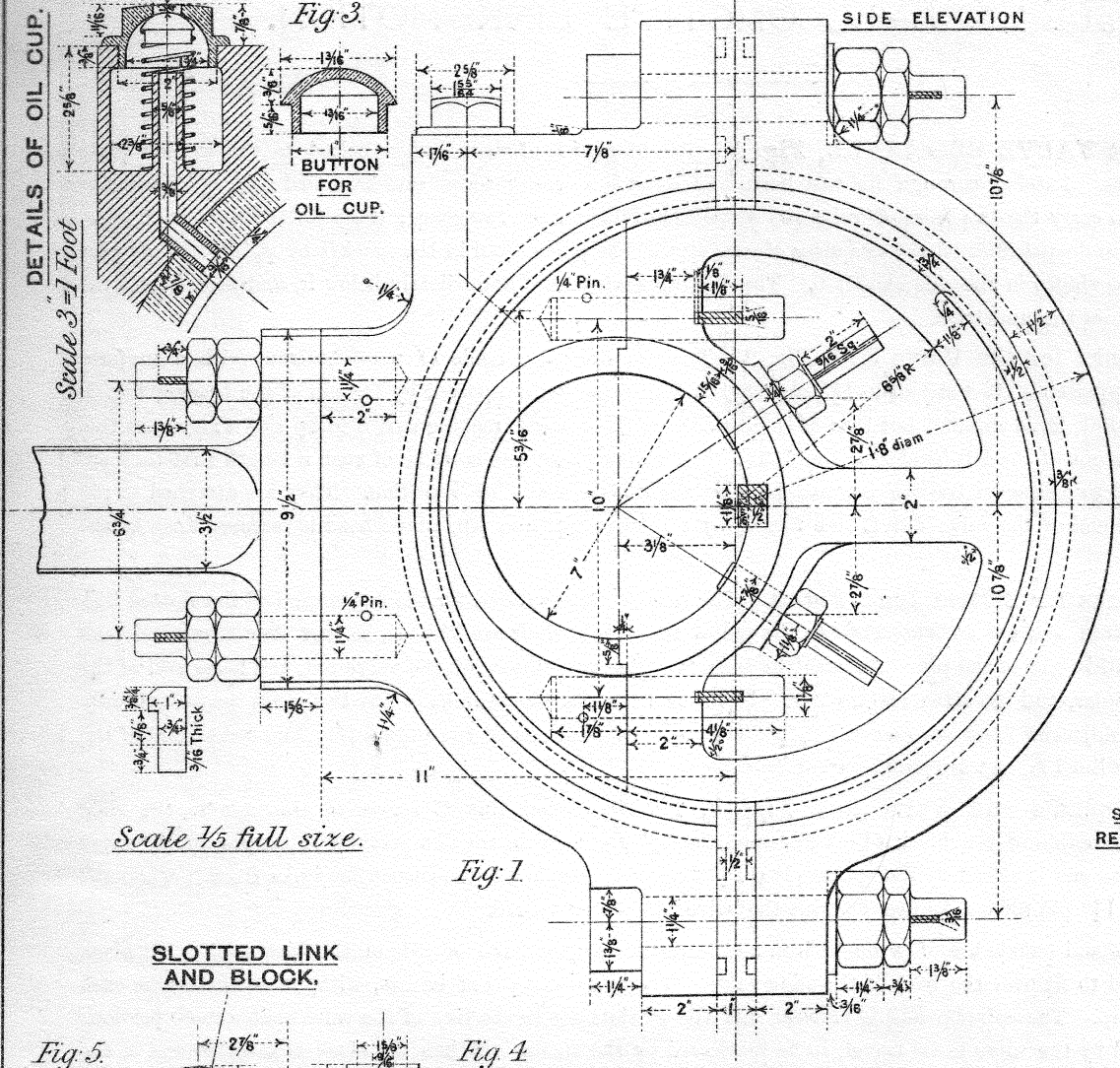
ECCENTRIC SHEAVE AND STRAPS.

DETAILS OF OIL CUP.

Scale 3"=1 Foot

Fig. 3.

SIDE ELEVATION



Scale 1/5 full size.

Fig. 1.

END ELEVATION

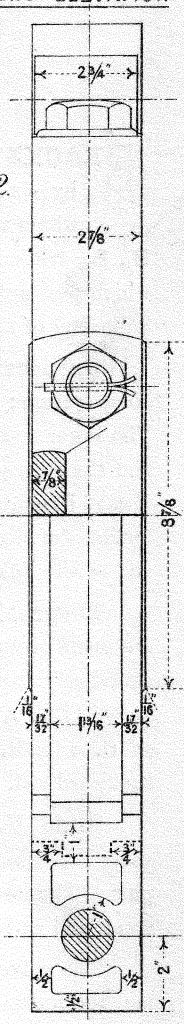


Fig. 2.

STRAP REMOVED.

SLOTTED LINK AND BLOCK.

Fig. 5.

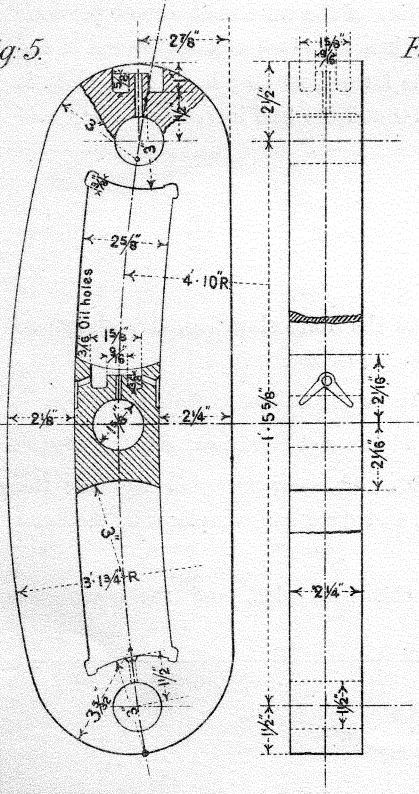


Fig. 4

ECCENTRIC RODS.

SIDE ELEVATION

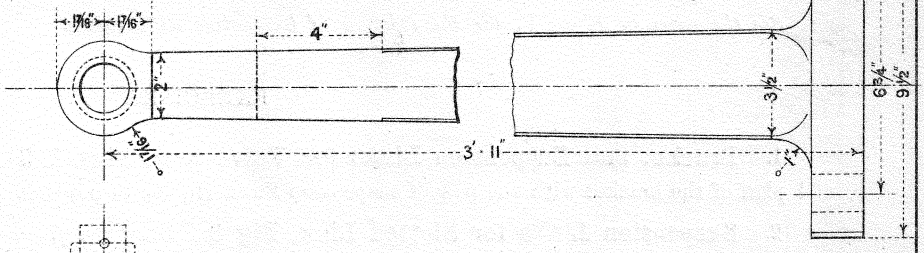


Fig. 6.

PLAN.

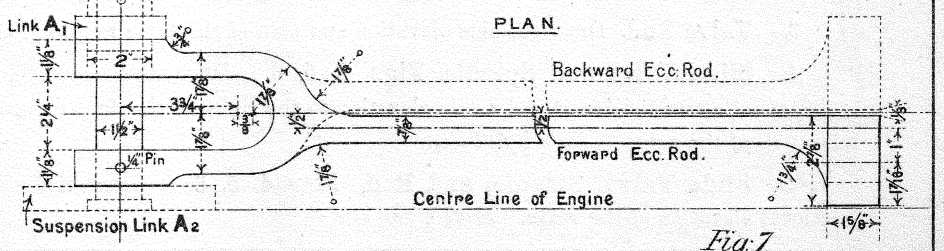


Fig. 7.

Scale 2"=1 Foot.

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Plate XXIV.—LOCOMOTIVE LINK MOTION.

BRACKET FOR VALVE ROD LINKS, Fig. 1. The bracket is of steel, and is bolted to the motion plate by six $\frac{3}{4}''$ bolts. Passing through its two horizontal arms is a wrought-iron case-hardened pin, $1\frac{1}{2}''$ diameter, which serves to carry the two pairs of valve rod suspension links for the two gears; those for the right-hand gear, B_1, B_2, are indicated in dotted lines on the two sides of one arm. The pin is fixed in the bracket by $\frac{5}{16}''$ split taper pins which pass across it as shown in the side elevation. The weight shaft passes immediately below it, and necessitates the hollowing of the arms on the underside.

Suspension Links for the Valve Rod, Fig 2 The two links are made of wrought iron, with a uniform cross section; their upper ends are widened to $1\frac{1}{2}''$, provided with oil cups, and supported by the pin of the bracket Fig. 1. The lower end of the link B_1 is circular, but that of the inside link B_2 is made rectangular, $3''$ deep $\times$ $5''$ wide, since this and the corresponding one of the left-hand gear touch, and their rubbing surfaces must be of such a length that they are always in contact, and so can never become jammed by any slight side shake or vibration. They are attached to the outsides of the forked end of the valve rod C (see Fig. 5) by a $1\frac{1}{2}''$ wrought-iron pin, whose head is recessed flush in the end of the link B_2.

Suspension Links for Slotted Link, Fig. 3. The rods A_1, A_2, required for the suspension of the slotted link are made of wrought iron, and the ends attached to the pin of the weight shaft are $3''$ wide, so that they touch and take up exactly half the full length of the pin. As with the links for the suspension of the valve rod, the lower end of the outside link A_1 is circular, and the other rectangular. In order that the inside links of the two gears may touch only at their ends, their adjacent faces are recessed $\frac{1}{16}''$. The relative positions of the slotted link, the forked end of the backward rod, and the links A_1, A_2, are shown in the drawing.

Slide Valve, Spindle and Valve Rod, Figs. 4, 5. The forked link C serves to transmit to the slide valve and spindle the motion of the block which fits upon the $1\frac{5}{8}''$ pin held in the two portions of the rod by $\frac{5}{16}''$ taper pins. The large forked end is closed by a distance piece $2\frac{1}{4}''$ long, and attached to the suspension links B_1, B_2; while the small end carries the $1\frac{1}{4}''$ pin for its connection with the valve spindle crosshead.

The valve spindle and buckle are of wrought iron and made in one piece, the outside of the latter being left black and the inside finished to fit over the back of the slide valve. The slide valve is of bronze, with $1''$ steam lap on each side and no exhaust lap. The cylinder face is vertical, and the $\frac{3}{8}''$ slots cut in the face of the valve enable those portions of it, never uncovered by the valve in its travel, to be lubricated by the steam. When the block is at either end of the slotted link, the travel of the valve is $3\frac{5}{16}''$, with a lead of $\frac{3}{16}''$, and the cut-off is the latest possible; but as the block is moved towards the centre, the valve travel diminishes, the cut-off takes place earlier and the lead increases. For "*mid gear*" the lead is $\frac{3}{8}''$, and the travel $2\frac{3}{4}''$.

See the notes to Plate V. for the friction of locomotive slide valves.

EXERCISES.

1. **Bracket and Suspension Links for Valve Rod, Figs. 1, 2.** Draw the front elevation, side elevation, and plan of the bracket with one pair of suspension links, B_1, B_2, in position. *Scale $\frac{1}{2}$ full size.*

2. **Suspension Links for Slotted Link, Fig 3.** Draw the given views and add a plan. *Scale $\frac{1}{2}$ full size.*

3. **Valve Rod.** Draw the side elevation and plan of the valve rod only, and add an end elevation. *Scale $\frac{3}{8}$ full size*

4. **Slide Valve and Spindle, Figs. 4, 5, 6.** Draw the elevation, plan and sectional plan, showing the valve spindle crosshead, and add a side elevation to the right of the first elevation, and draw and complete the sectional elevation of the valve. *Scale $\frac{1}{2}$ full size.*

*5. **Slide Valve, Spindle, and Rod, Figs 4, 5, 6.** Draw the side elevation, plan, and the completed sectional elevation of the valve. *Scale $\frac{3}{8}$ full size.*

* This Exercise is intended for Advanced Students.

DETAILS OF LOCOMOTIVE LINK MOTION.

BRACKET FOR VALVE ROD LINKS.

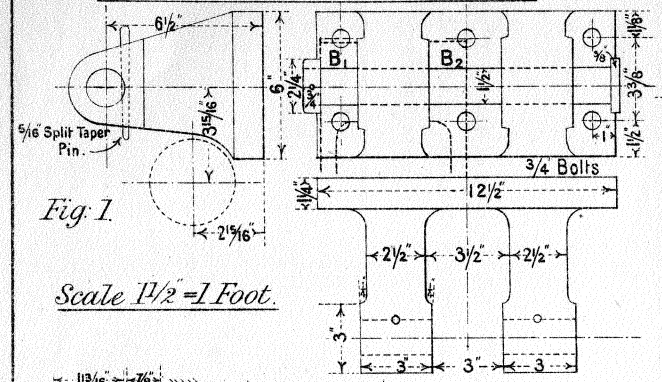


Fig. 1.

Scale 1½" = 1 Foot.

SUSPENSION LINKS FOR VALVE ROD.

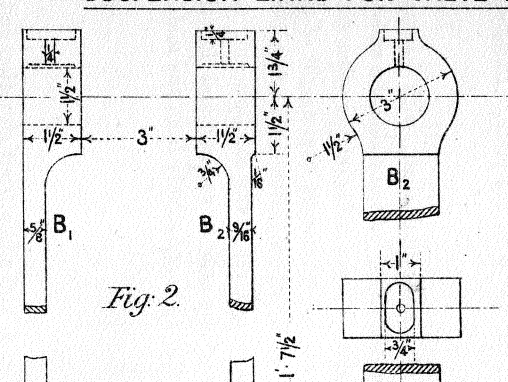


Fig. 2.

SUSPENSION LINKS FOR SLOTTED LINK.

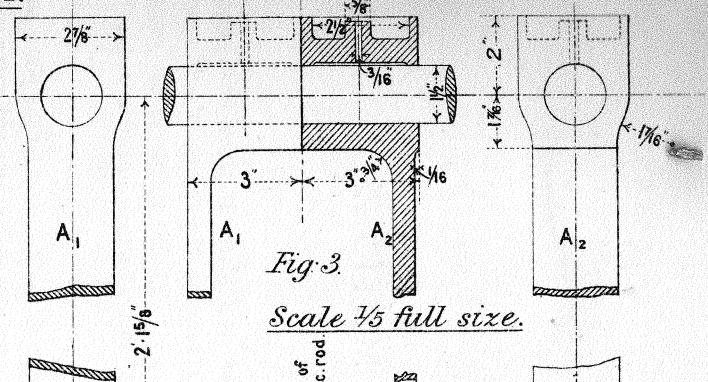
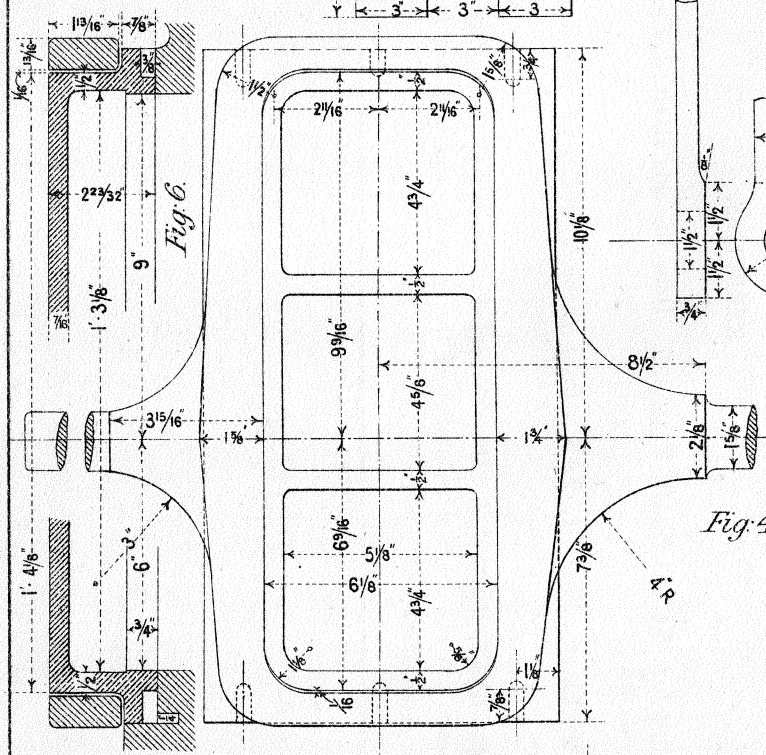


Fig. 3.

Scale ⅕ full size.



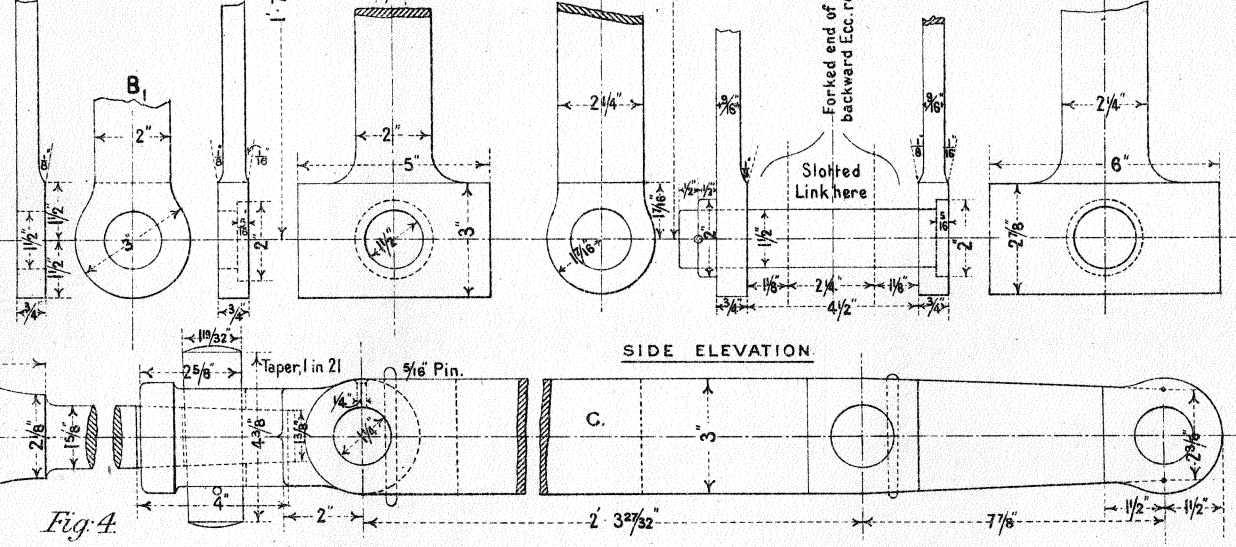


Fig. 4.

SLIDE VALVE, SPINDLE AND VALVE ROD.

Scale ⅕ full size.

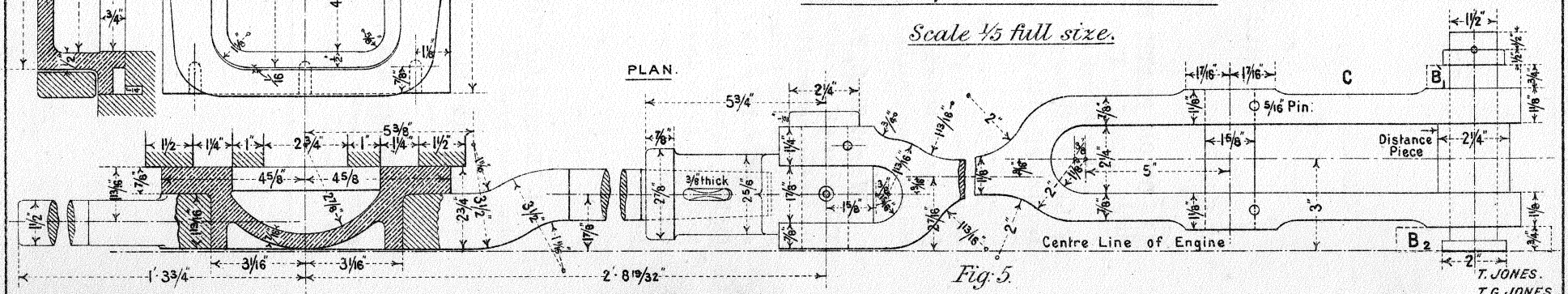


Fig. 5.

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Plate XXV.—LOCOMOTIVE LINK MOTION.

MOTION PLATE, Figs. 1, 2, 3. The motion plate is a well annealed cast steel plate, 1″ thick, with edges widened to 3″, and formed with flanges, which, when planed, fit accurately between the frames 4′ – 2″ apart. It is secured to the frames by $\frac{7}{8}$″ turned rivets, countersunk and riveted cold. The large hole in the centre of the plate is for the passage of the eccentric rods, and the two smaller ones, 2′ – 4″ apart, for the connecting rods; the two slots, $9\frac{1}{4}$″ × $1\frac{3}{4}$″, near the top, are for the arms of the weight shaft.

The T end of each wrought-iron slide bar is secured by two $1\frac{1}{4}$″ wrought-iron bolts to the lugs cast on the plate, and has two brass liners $\frac{1}{4}$″ thick, for the purpose of adjusting the bar. The bracket for the support of the valve rod suspension links is bolted to the top facing, and the bearings for the support of the weight shaft are cast with the plate. Details of the bearing are given in Figs. 4 and 5.

Weight Shaft, Figs. 6 and 7. The wrought-iron weight shaft consists of a horizontal shaft, with journals 3″ diameter × 4″ long at its ends, and two parallel arms projecting on either side of the shaft. At one side the ends of the arms are connected by a $1\frac{1}{2}$″ pin, which carries the four suspension rods for the slotted links, while on the other ends are bolted cast-iron balance weights, $11\frac{5}{8}$″ diameter × 5″ wide. These weights serve to counteract the weight of the slotted link and eccentric rods, and thus enable a change in the position of the gear to be effected with little effort. At the left-hand end of the shaft is the reversing arm, which is connected with the reversing lever in the cab by a long rod (not shown in the drawings), and bent outwards a distance of $3\frac{1}{8}$″. For "*mid gear*" the arm is vertical, and for the positions of "*full forward*" and "*full backward gear*" the end of the arm is $7\frac{1}{4}$″ and $9\frac{3}{8}$″ respectively from the middle position.

EXERCISES.

1. **Bearing for Weight Shaft, Figs. 4, 5.** Draw the side elevation, Fig. 4, and add a front elevation and a plan. *Scale* $\frac{3}{4}$ *full size.*

*2. **Motion Plate, Figs. 1, 2, 3.** Draw the complete front elevation, sectional elevation, and plan. *Scale* 2″ = 1 *foot.*

*3. **Weight Shaft, Figs. 6, 7.** Draw the end elevation and plan—showing the full lengths of the shaft and reversing arm—and add a complete side elevation of the reversing arm projected from the end elevation, so as to show its true shape. *Scale* 3″ = 1 *foot.*

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* These Exercises are intended for Advanced Students.

DETAILS OF LOCOMOTIVE LINK MOTION.

SECTIONAL ELEVATION AT A. B.

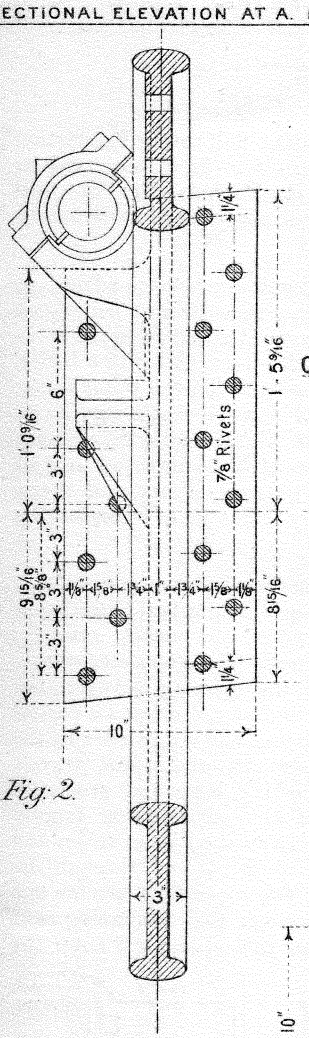


Fig. 2.

Scale 1/10 full size.

CAST STEEL MOTION PLATE.

HALF FRONT ELEVATION

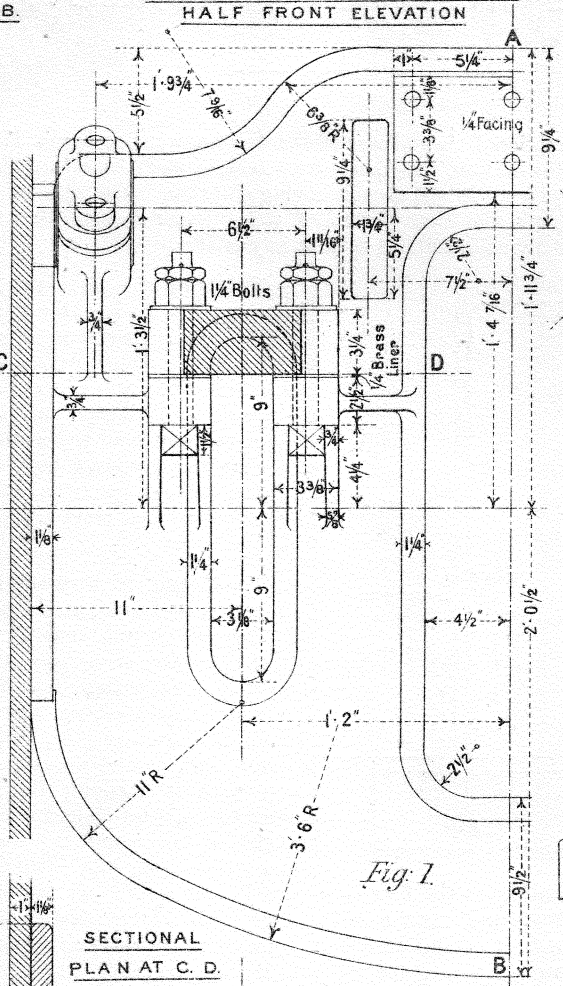


Fig. 1.

BRACKET FOR WEIGHT SHAFT.

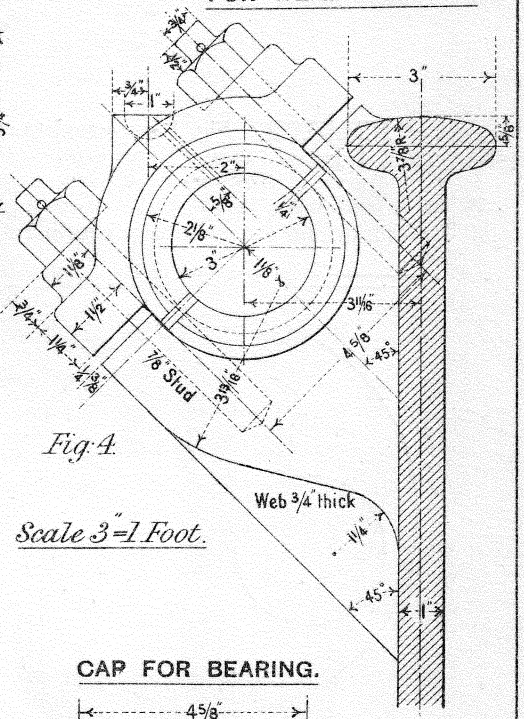


Fig. 4.

Scale 3"=1 Foot.

CAP FOR BEARING.

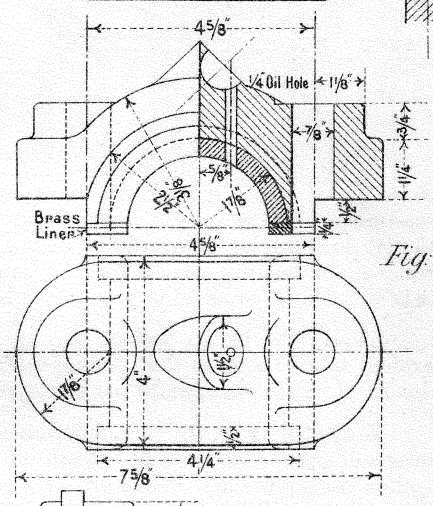


Fig. 5.

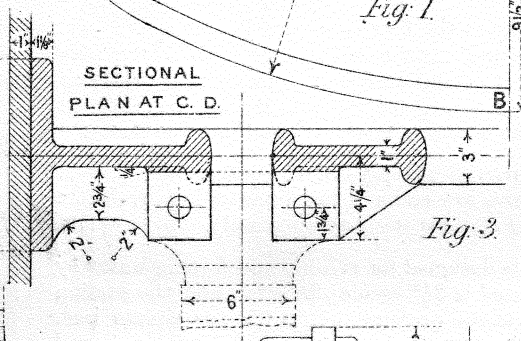


Fig. 3.

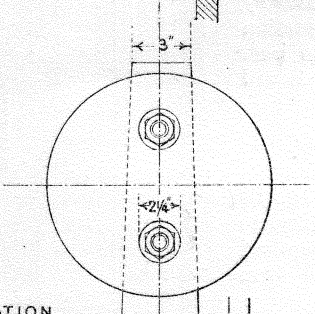
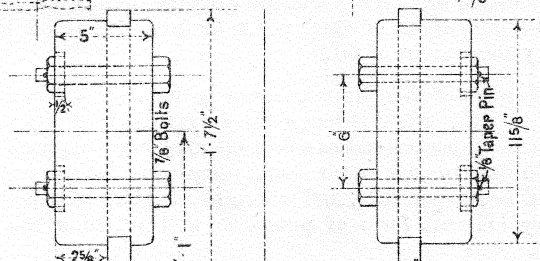


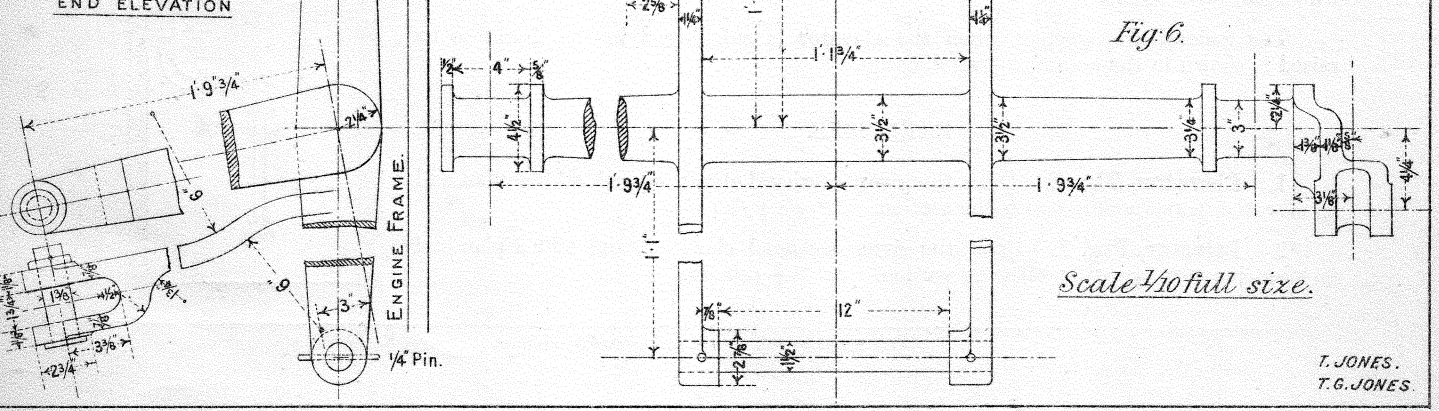
Fig. 7.

WEIGHT SHAFT.



PLAN.

Fig. 6.



Scale 1/10 full size.

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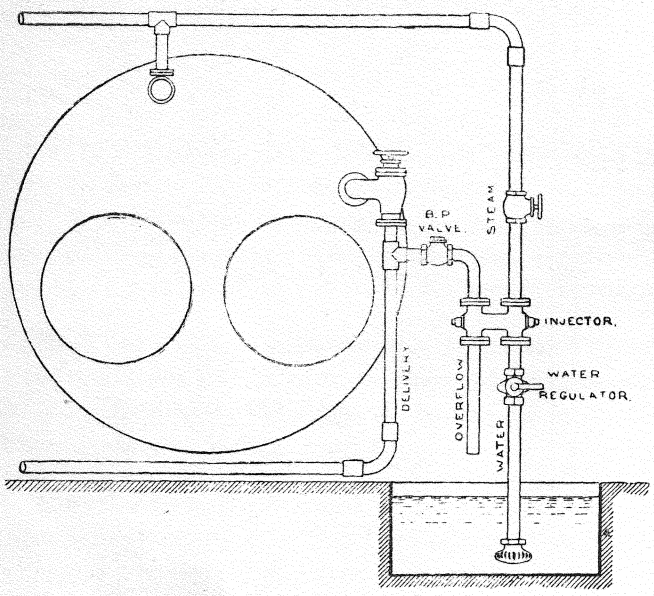
Plate XXVI.—INJECTOR AND ELEVATOR.

INJECTOR. Fig. 1 is a complete sectional view of one of the well-known Gresham's Patent Self-acting Re-starting Injectors; it is of ample capacity for feeding two Lancashire boilers, each of 8 ft. diameter × 30 ft. long, and its arrangement for such a purpose is shown in the accompanying diagram. The size of pipes required for use with this instrument is $1\frac{1}{2}''$ inside diameter, and the construction of the injector is such, that all the internal parts can be withdrawn for examination or cleaning without detaching it from any of the pipes.



The injector is an instrument which takes advantage of the well-known law that steam issues from a boiler at a velocity greatly in excess of water issuing from the same boiler. For instance, if two holes were drilled in a boiler, one in the steam space, and the other in the water space, the steam would escape out of the boiler at a very much greater velocity than the water. If, therefore, the velocity of the steam, or a large portion of it, be imparted to a jet of water, this jet would have a greater velocity, and, therefore, would possess more energy than a jet of water issuing from the boiler.

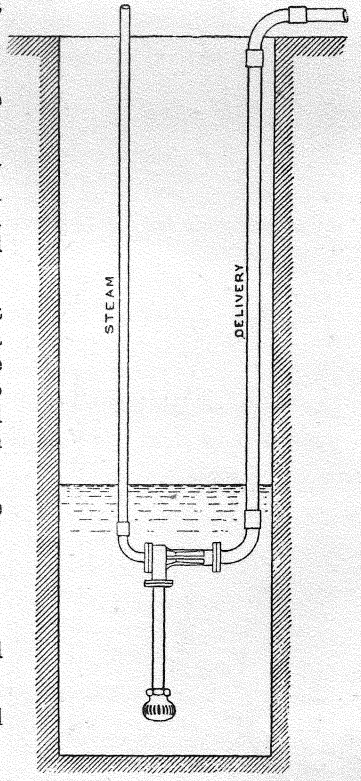
The **Cones** of this self-acting injector are made in four parts; beginning at the top, the first is the *steam cone* C; 2nd, the *lifting cone* D; 3rd, the *moving cone* E; 4th, the *receiving or delivering cone.* The steam on entering the steam cone passes out at the opening between the lifting and moving cones, and in doing so creates a partial vacuum in the water pipe, and thus the water rises to the injector, and, coming in contact with the steam, travels along with it through the lifting cone and gradually condenses it, the velocity of the steam being largely transferred to the water. The combined jet of steam and water passes from the lifting cone into and through the moving cone, which it then lifts to its seating on the bottom of the lifting cone; and these two cones then become one *combining cone* (the cone in which the steam and water combine together). After passing through this combining cone the jet flows out at the overflow space until it attains sufficient velocity to carry itself across this space, and enter the receiving or delivery cone. When it reaches this point its velocity is so great that it is sufficiently powerful to pass through the back-pressure valve and into the boiler.

Should the jet be broken, say by a partial stoppage of the water supply, it is evident that so soon as the working conditions are restored the same action, as before described, takes place, and thus the injector restarts itself automatically.

Elevator, Fig. 2. This instrument is designed for raising and forcing water by means of a jet of steam. The steam pipe used is $2\frac{1}{2}''$ inside diameter, and the suction and delivery pipes $3\frac{1}{2}''$ diameter. With a steam pressure of 60 lbs. per square inch this elevator will lift 16,650 gallons of water per hour to a height of 10 ft., or it will raise a smaller quantity to a height of 60 ft.

The theory of the action of this jet apparatus is the same as for the injector, but as it is only required to start work through an empty delivery pipe—not against a boiler pressure as with the injector—no overflow openings are required. It should be pointed out that in addition to the water being lifted and forced from one level to another it is also raised in temperature, and where this heating of the water is required the steam jet is a very efficient form of pump, as well as being the simplest form which can be designed.

The general arrangement when the elevator is submerged in the liquid to be raised is shown in the accompanying diagram.



EXERCISES.

1. **Elevator, Fig. 2.** Draw the given sectional elevation, and add a plan and an elevation corresponding with the section. *Scale $\frac{1}{2}$ full size.*

*2. **Injector, Fig. 1.** Draw the given sectional elevation, and add a plan and an elevation corresponding with the section. *Scale $\frac{3}{4}$ full size.*

* This Exercise is intended for Advanced Students.

SELF-ACTING RE-STARTING INJECTOR.

SECTIONAL ELEVATION

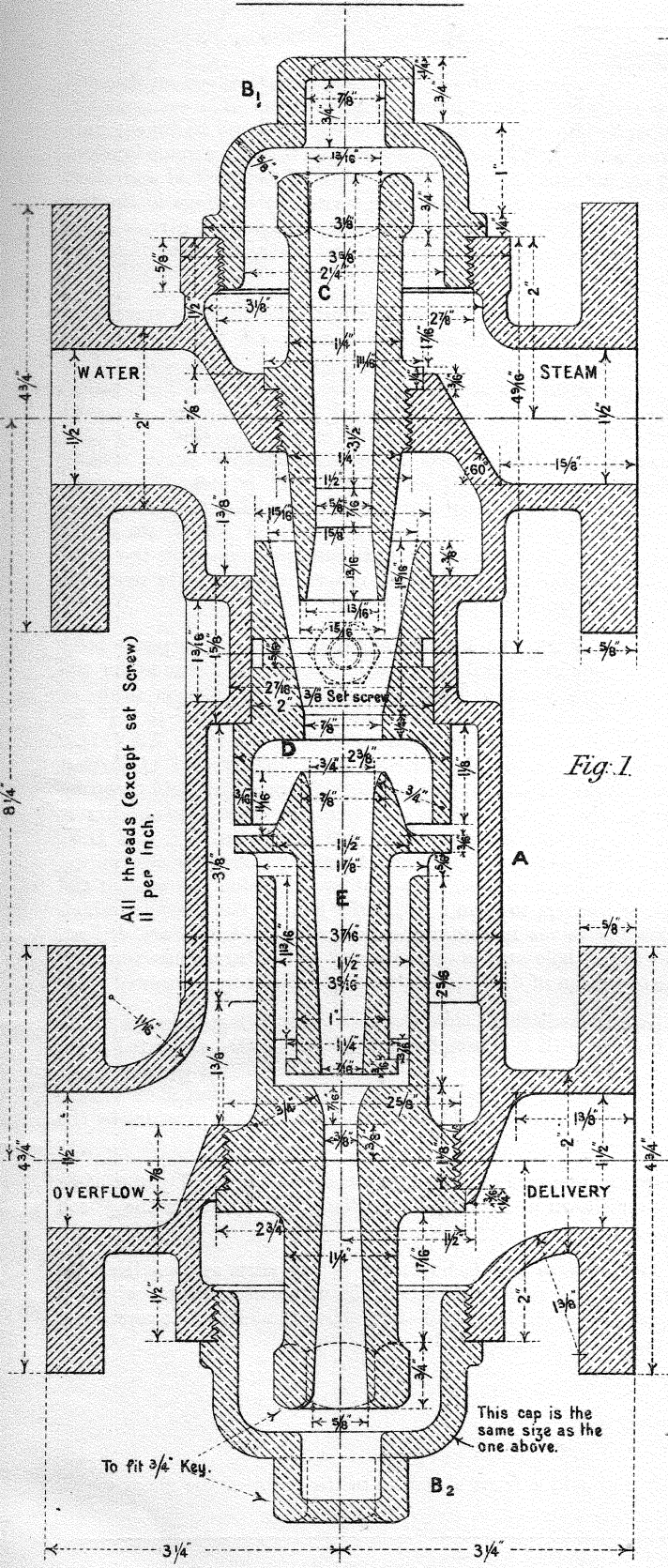


Fig. 1.

Scale 6" = 1 Foot.

ELEVATOR.

SECTIONAL ELEVATION

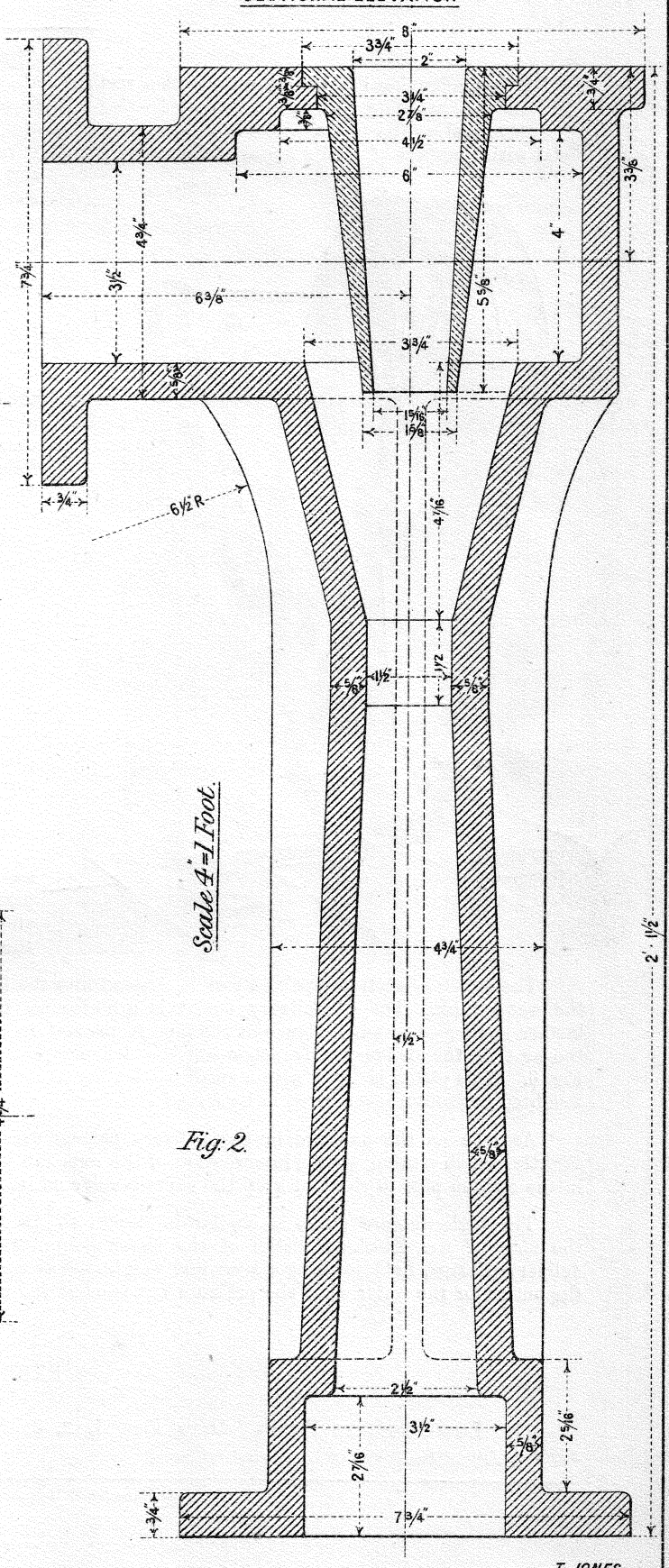


Fig. 2.

Scale 4" = 1 Foot.

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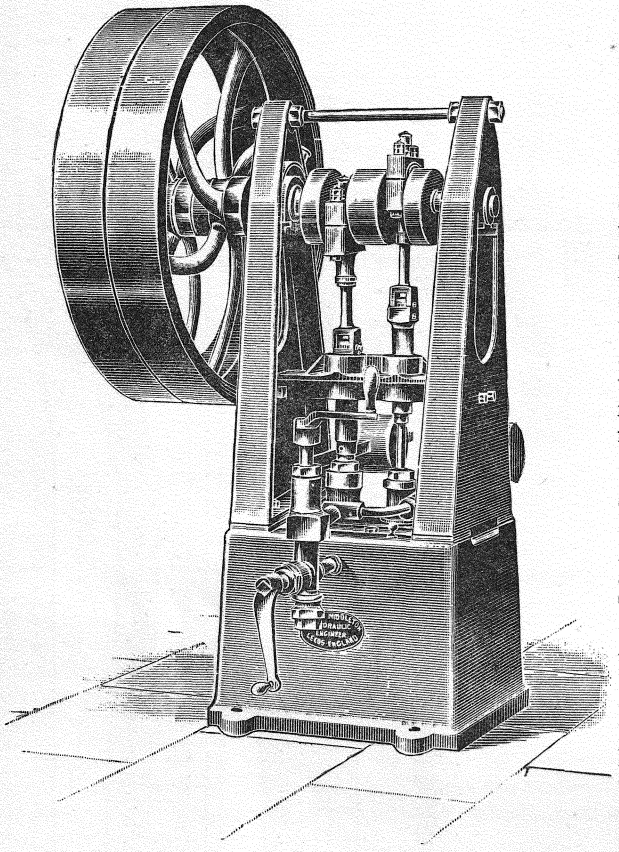
Plate XXVII.—VERTICAL HYDRAULIC PUMP.

THE accompanying illustration represents a vertical hydraulic pressure pump—of which details are given on this and the two following plates—suitable for feeding a hydraulic packing press without the intervention of an accumulator. Mounted on the top of a cast-iron tank, containing the water supply, are two single-acting pumps of hydraulic gun-metal with plungers of Muntz metal of diameters $\frac{7}{8}''$ and $2''$ respectively. The two plungers pass through a guide bracket, and are actuated by a two-throw crank of forged steel and short connecting rod, the former being carried by bearings in the two vertical standards. The shaft, being belt-driven, carries a fast and a loose pulley, 4 ft. diameter, and makes 60 revolutions per minute.



Both plungers work together until the pressure exerted by the pumps reaches 12 cwts. per square inch, and then by an ingenious device the low-pressure pump is "knocked off" in consequence of its suction valve being lifted by a light rod in the suction pipe, and prevented from falling on its seat during the down-stroke of the plunger: in this way the water in the suction pipe of the low-pressure pump simply follows the plunger up and down, and is not discharged. With the high-pressure pump working alone the pressure is allowed to rise up to 2 tons per square inch before its safety valve lifts. For the above maximum pressure with the shaft running at 60 revolutions per minute about 3 horse power is required to work the pump.

Low-Pressure Pump, Figs. 1 to 6. The pump body of hydraulic gun-metal is bolted by its circular flange to the top of the tank by two $\frac{5}{8}''$ studs. The $2''$ plunger is made of Muntz metal, and its upper end is turned down to $1\frac{1}{8}''$ for connection with the cast-iron guide (Fig. 5, Plate XXVIII.). The packing for the plunger consists of an inverted U leather placed over a thin supporting ring of brass and held down by the screwed gland. Since the pump is only single-acting it has one suction valve and one delivery valve, S.V. and D.V. respectively—detailed in Figs. 4 and 5; their lifts are limited by the $\frac{3}{4}''$ screws above, the shoulders of which bed against the leather washers to form a hydraulic joint. The passages which place the valves in communication with the barrel are drilled, and the $1''$ hole on the opposite side of the barrel, necessary for the operation of drilling, is afterwards closed by a screwed plug.

The cast-iron suction pipe and rose is screwed into the base immediately below the suction valve, and hangs inside the water tank. The $\frac{5}{8}''$ delivery outlet is a horizontal branch with a screwed end, against which—separated by a leather washer—the small flange of the pipe is pressed by a brass socket piece. The $\frac{1}{8}''$ diameter drilled passage above the seat of the delivery valve connects the delivery passage with the $\frac{3}{8}''$ vertical hole containing the knock-off piston, Fig. 6. This piston is fitted with a small hat leather at its lower end, and is held down under a definite pressure by the weighted horizontal lever fitted in its forked end.

As soon as the pressure in the delivery passage exceeds a pressure of about 12 cwts., the knock-off piston rises slightly, which motion, by the intervention of the rods and lever shown in Figs. 3 and 4, Plate XXIX., causes the $\frac{1}{4}''$ rod in the suction pipe to rise and keep the suction valve off its seat.

The high-pressure pump is similar in design to the low-pressure pump, but most of its parts are smaller. In the place of the knock-off piston of the latter pump, there is the safety valve (Fig. 7), in communication with the delivery passage, held down by a lever and weight. The small dotted circle immediately above the valve seat represents the outlet for the water when the pressure has reached the maximum working limit.

EXERCISE.

*1. **Low-Pressure Pump.** Draw Figs. 1, 2, 3, 4, and add a front elevation to the right of the given views. *Scale* $\frac{1}{2}$ *full size.*

* This Exercise is intended for Advanced Students.

TWO-THROW VERTICAL HYDRAULIC PRESSURE PUMP.

DETAILS OF LOW-PRESSURE PUMP.

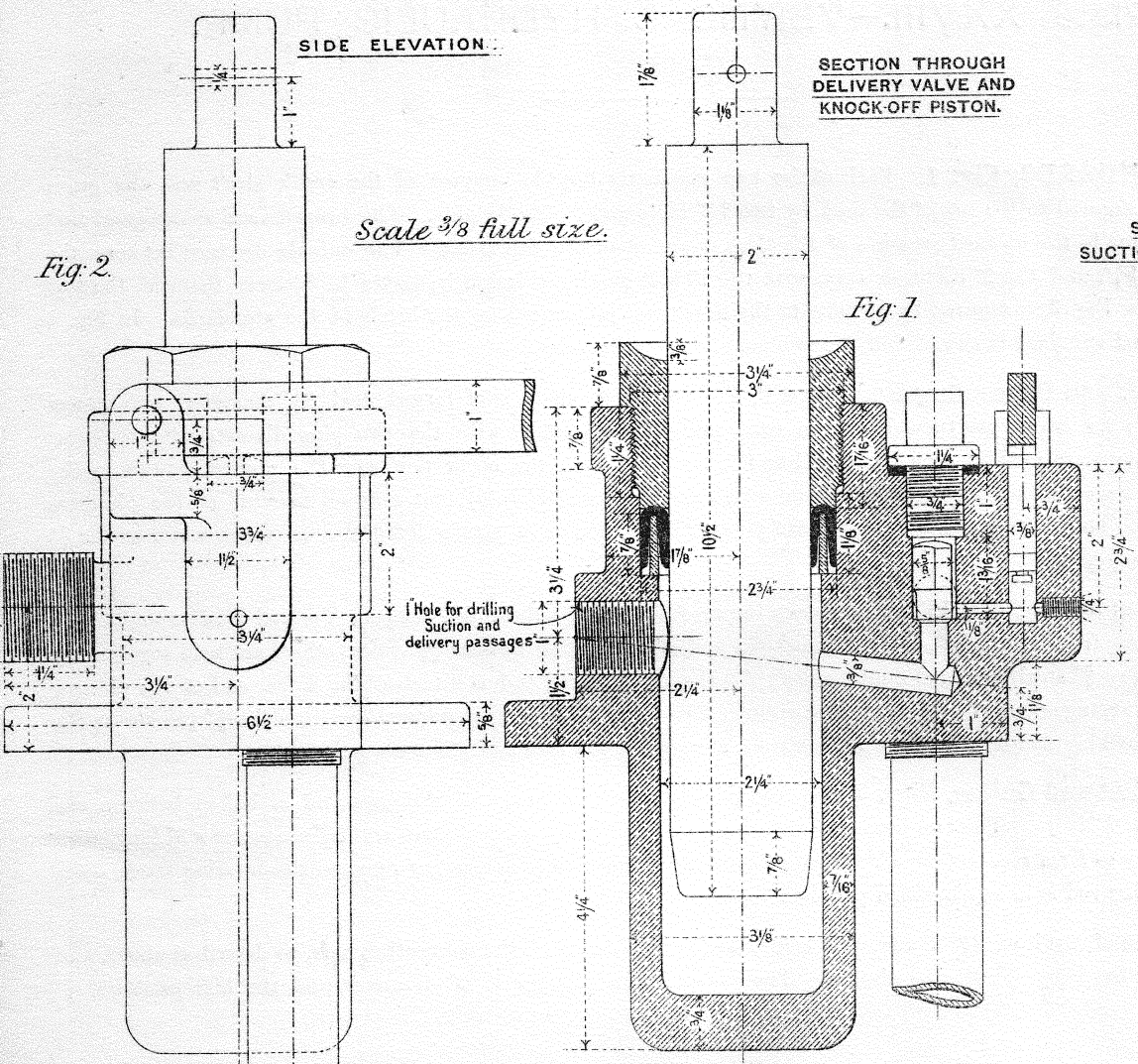
SIDE ELEVATION.

Scale 3/8 full size.

Fig. 2.

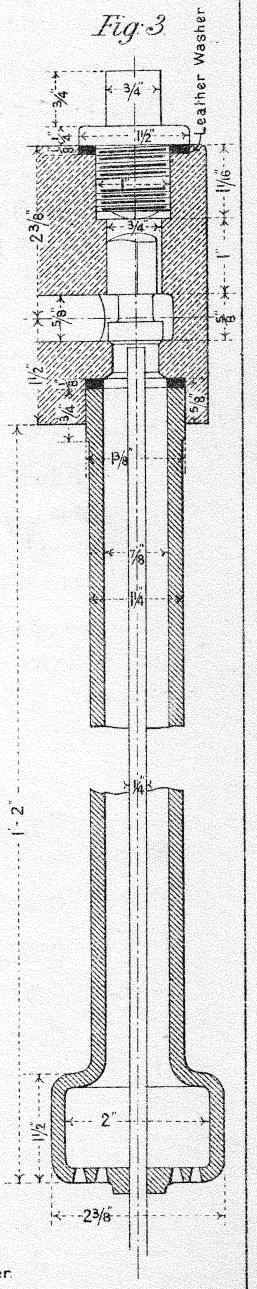
SECTION THROUGH DELIVERY VALVE AND KNOCK-OFF PISTON.

Fig. 1.



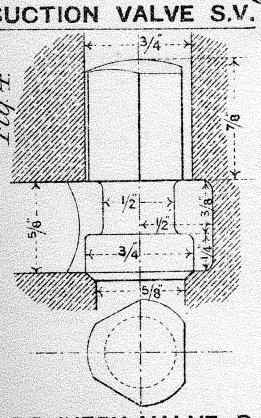
SECTION THROUGH SUCTION PASSAGE AND PIPE.

Fig. 3.



SUCTION VALVE S.V.

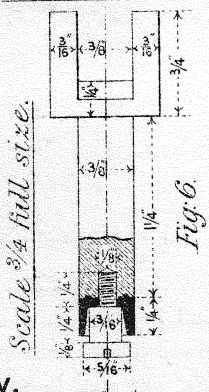
Fig. 4.



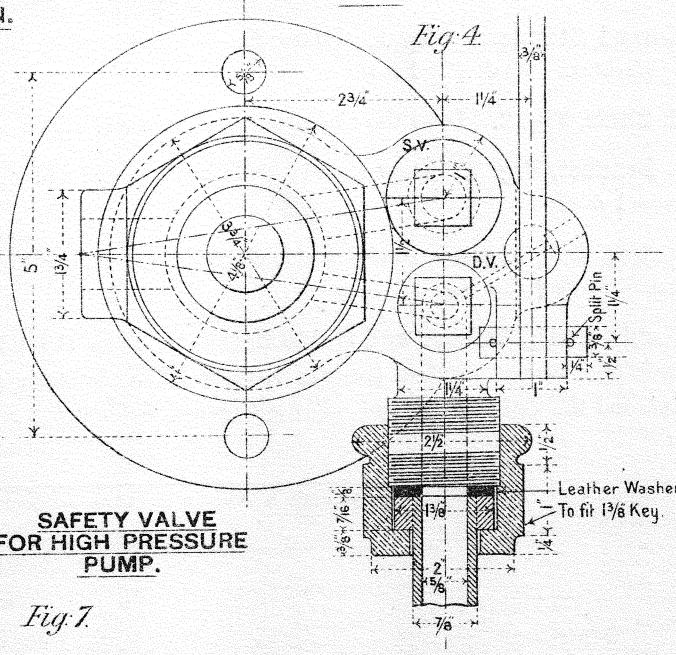
KNOCK-OFF PISTON.

Scale 3/4 full size.

Fig. 6.

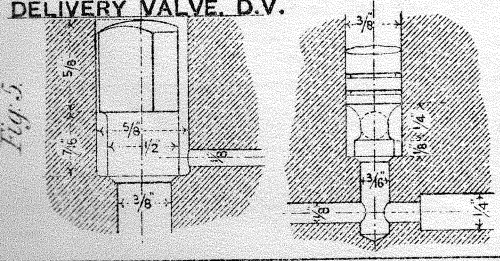


PLAN.



DELIVERY VALVE. D.V.

Fig. 5.



SAFETY VALVE FOR HIGH PRESSURE PUMP.

Fig. 7.

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Plate XXVIII.—VERTICAL HYDRAULIC PUMP.

PUMP STANDARDS, Fig. 1. Each of the two standards for the support of the crank shaft and the guide bracket is secured to the top of the tank by two $1\frac{1}{8}''$ bolts and $\frac{1}{2}''$ steady pins. The bearings are so designed that no stress due to the upward pressure of the shaft is put upon the cap bolts. The outside distance between the standards is $1' - 9\frac{3}{4}''$, and the 2″ cast-iron stay, with the 1″ bolt passing through it, serves to connect them at the top. The guide bracket, Fig. 3, is secured by $\frac{1}{2}''$ bolts to the horizontal projections on the inside of the standards. In Fig. 1 only the right-hand standard is shown, but the two are alike in all respects.

Crank Shaft and Connecting Rod, Figs. 2, 4. The crank shaft is of forged steel, $2\frac{1}{2}''$ diameter, with a total length of $3' - 0\frac{3}{8}''$: the cranks are turned out of a solid piece $7\frac{1}{2}''$ diameter, with the two pins diametrically opposite. When the two pumps are working, one pump will be forcing water while the other performs the upward suction stroke so that there will be a continuous delivery, but one which fluctuates considerably, not only on account of the plungers being crank driven, but because the 2″ low-pressure plunger discharges in a stroke 5·2 times as much water as the $\frac{7}{8}''$ high-pressure plunger.

The connecting rod, Fig. 4, is 11″ long between the centres, and of substantial design. The rod is of wrought iron, varying in diameter from $1\frac{3}{4}''$ to $1\frac{1}{8}''$, and the crank-pin end is fitted with brasses $\frac{5}{16}''$ thick, which are held together by the cap and the two $\frac{5}{8}''$ steel bolts and double nuts. To the small forked end is attached the upper end of the plunger guide, and by the arrangement of cotter and semi-circular brass, the guide is kept pressed down on the $\frac{5}{8}''$ pin across the end, so that no knocking will occur on the down stroke, even when the hole and pin are worn.

Guide Bracket and Guides, Figs. 3, 5. The guide bracket is made of cast iron, and is bolted between the pump standards by $\frac{1}{2}''$ bolts. The two holes through which the plunger guides pass are $2\frac{1}{4}''$ diameter × 3″ long, with lips cast on the top to form recesses for oil. The support thus given to each plunger removes the bending strain on it when the connecting rod is in any inclined position.

The guides are of cast iron, $2\frac{1}{4}''$ diameter, attached to the small ends of the connecting rods, as described above, and the plungers are fixed by $\frac{1}{4}''$ pins as shown. The low-pressure plunger is 2″ diameter, and the high-pressure, $\frac{7}{8}''$ diameter.

EXERCISES.

1. **Right-hand Standard, Fig. 1.** Draw the two given views, and add a plan and a front elevation to the right of the side elevation. *Scale* 4″ = 1 *foot.*

2. **Crank Shaft, Fig. 2.** Draw the two given views, and add a plan and an end elevation. *Scale* 4″ = 1 *foot.*

3. **Guide Bracket, Fig 3.** Draw the two given sections, and add elevations corresponding with them, and also a plan. *Scale* 4″ = 1 *foot.*

4. **Connecting Rod, Fig. 4.** Draw the side elevation and plan as given, and add an end elevation to the left of the side elevation. *Scale* $\frac{3}{4}$ *full size.*

*5. **Standards, Shaft, Pulleys and Guide Bracket.** Draw the side and front elevations and plan, showing the two brackets in their correct positions (see Fig. 1, Plate XXIX. for their distance apart) connected by the top stay and guide bracket, and the shaft and pulleys. *The pulleys are 4′ diameter × 5″ wide, and must be designed by the student. Scale 3″ = 1 foot.*

* This Exercise is intended for Advanced Students.

TWO-THROW VERTICAL HYDRAULIC PRESSURE PUMP.

RIGHT HAND STANDARD.

Scale 2"=1 Foot.

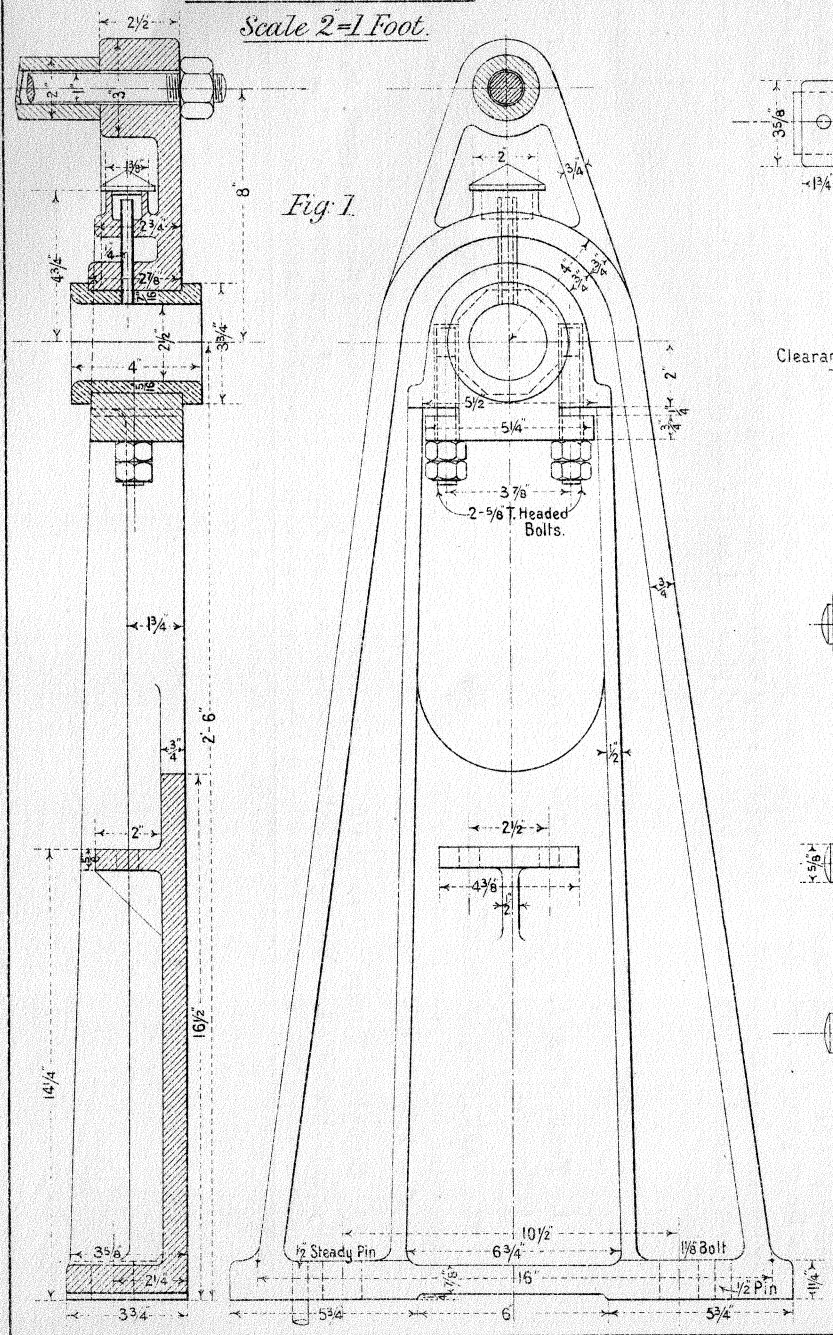
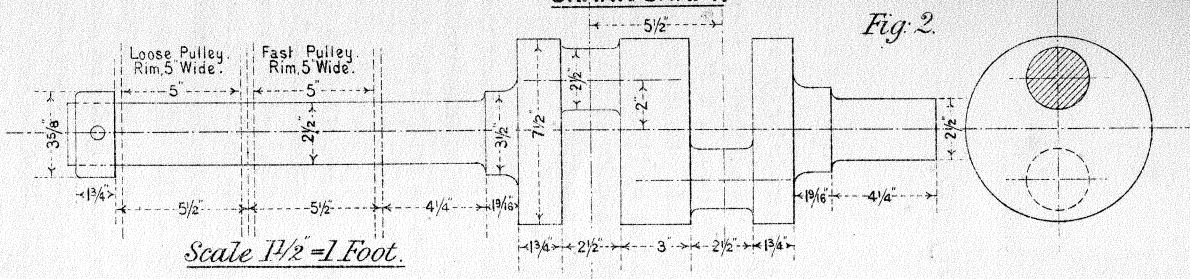


Fig: 1.

CRANK SHAFT.



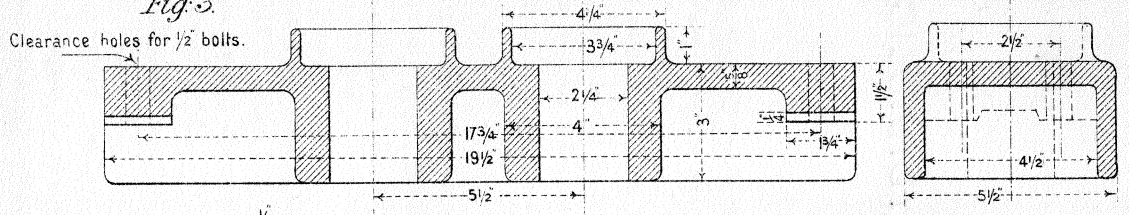
Scale 1½"=1 Foot.

Fig: 2.

GUIDE BRACKET.

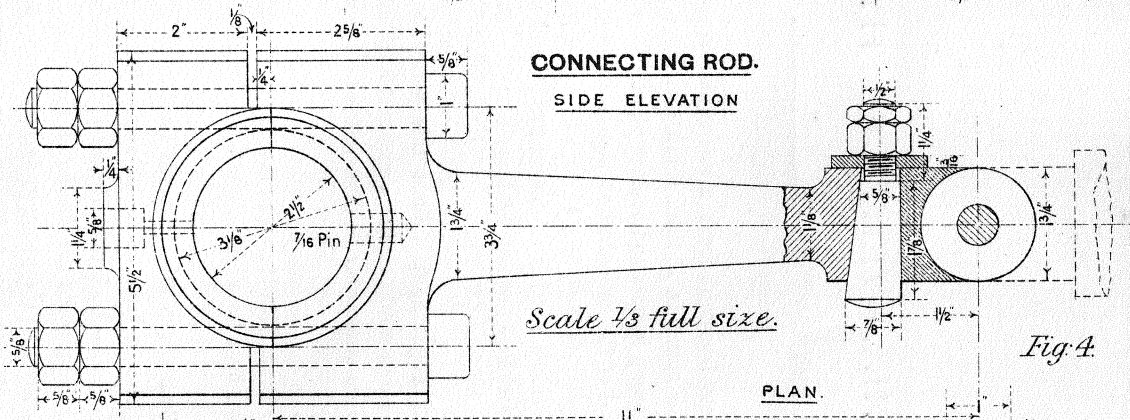
Scale ⅓ full size.

Fig: 3.



CONNECTING ROD.

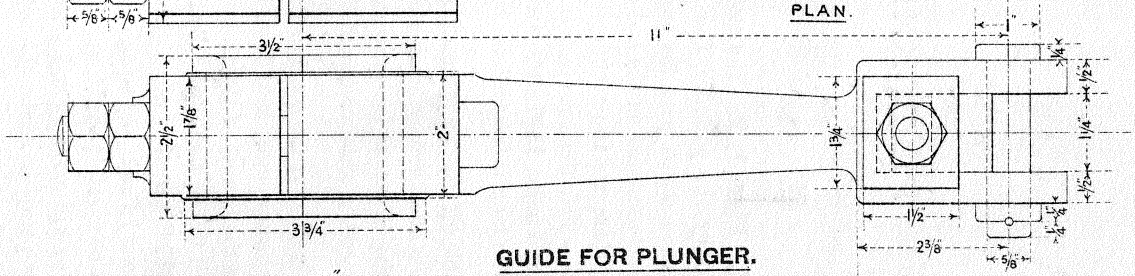
SIDE ELEVATION



Scale ⅓ full size.

Fig: 4.

PLAN.



GUIDE FOR PLUNGER.

Scale 3"=1 Foot

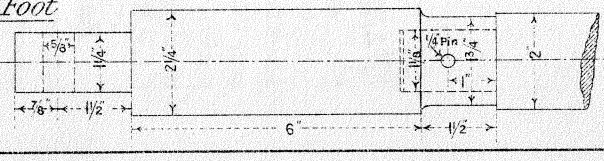


Fig: 5.

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Plate XXIX.—VERTICAL HYDRAULIC PUMP.

TANK, Figs. 1, 2. The cast-iron tank forms a substantial base for the pump, as well as a reservoir for the water used by the pumps. The metal is 1″ thick throughout, and the top is strengthened by two parallel $\frac{3}{4}$″ ribs, between which pass the pump barrels and suction pipes. The tank is supplied with water through a 2″ pipe, whose flange—screwed on the end of the wrought-iron pipe—is bolted near the base by three $\frac{1}{2}$″ studs. On the top, at each side, there are two rectangular facings, 6″ × 4″, to which the feet of the standard are bolted by $1\frac{1}{8}$″ bolts. The portion to which the two pumps are fixed is thickened to $1\frac{1}{2}$″, and planed. To give access to the inside of the tank there are two holes, $13\frac{3}{4}$″ × 4″, on the top, closed by loose cast-iron covers, $\frac{1}{4}$″ thick, which simply rest upon projections below. The tank is bolted down by four $\frac{7}{8}$″ bolts.

Knock-off Arrangement, Figs. 3, 4. Since this pump is used for feeding a hydraulic press without the intervention of an accumulator, which would ensure a constant load on the pump, it is necessary to have an arrangement whereby the larger or low-pressure pump may be disconnected automatically as soon as the pressure required by the presses exceeds a certain amount.

As described in the notes to Plate XXVII., there is a knock-off piston, in communication with the delivery outlet of the low-pressure pump, held down by a lever A and weight. (See Figs. 3 and 4.) The lever A is connected with the lever B at the bottom of the tank by the rod C, and from a point $4\frac{1}{2}$″ from the fulcrum end of B a vertical rod D passes up through the suction pipe. By a slight adjustment of the length of the rod C, the end of D is made just to clear the underside of the suction valve when the latter is on its seat. When the pressure in the delivery pipe reaches a certain value—about 12 cwts. per square inch—the knock-off piston rises slightly, and so lifts the lever A: this motion causes the rod D to move upwards, and so prevents the closing of the suction valve. Under these conditions the water in the suction pipe will move up and down with the plunger, and no water will be discharged from the pump. In this manner the larger pump is rendered inactive so long as the pressure in the delivery pipe does not fall; and in the event of a decrease, the lever A immediately falls, and the pump again discharges water into the press. The lift of the knock-off piston is limited to a very small amount by the slotted plate fixed on the back of the tank, and through which the lever A passes.

EXERCISES.

1. **Tank, Figs. 1, 2.** Draw the two given views, and add a sectional side elevation through the centre of the tank to the right of Fig. 1 *Scale* 3″ = 1 *foot.*

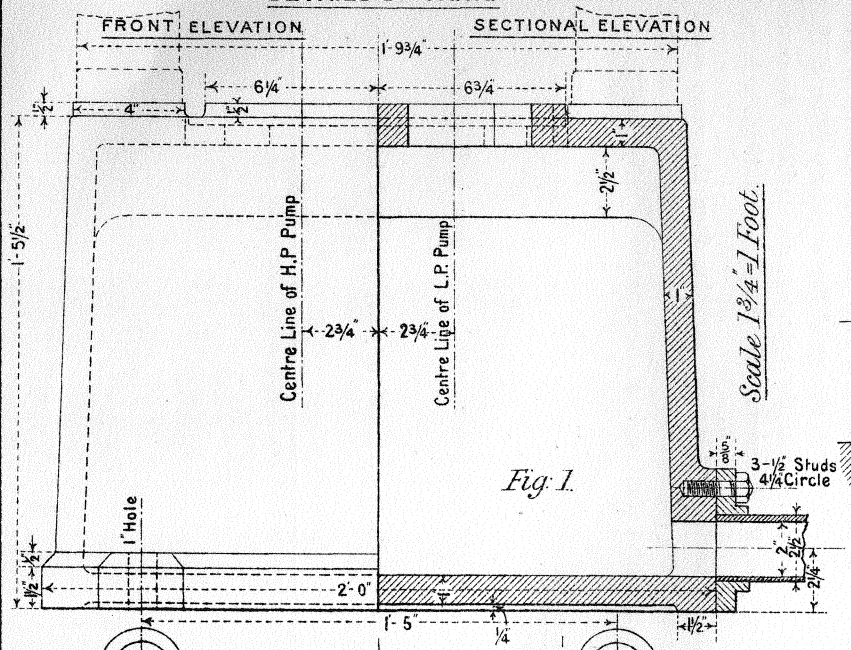
*2. **Tank, with knock-off Arrangement.** Draw the sectional side elevation of the tank, showing the knock-off arrangement and the pump in outside elevation; and also a plan, indicating in dotted lines the parts inside the tank. *Scale* 4″ = 1 *foot.*

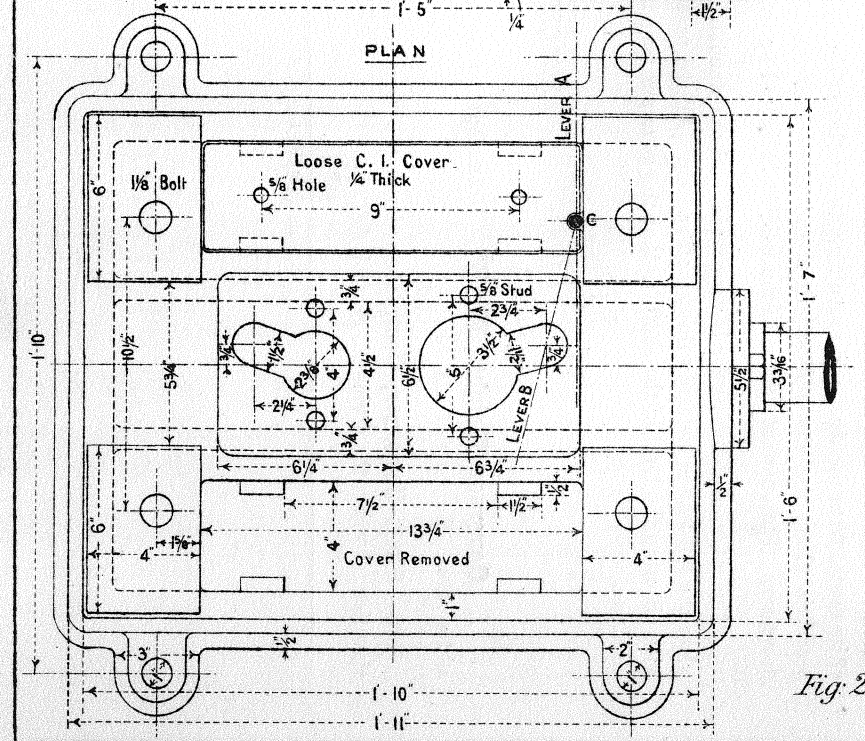
*3. **Complete Pump.** Draw the front and the side elevation and plan, showing the tank, standards, shaft, pulleys, guide bracket, one connecting rod and the low-pressure pump with the knock-off arrangement. *Scale* 2″ = 1 *foot.*

* These Exercises are intended for Advanced Students.

TWO-THROW VERTICAL HYDRAULIC PRESSURE PUMP.

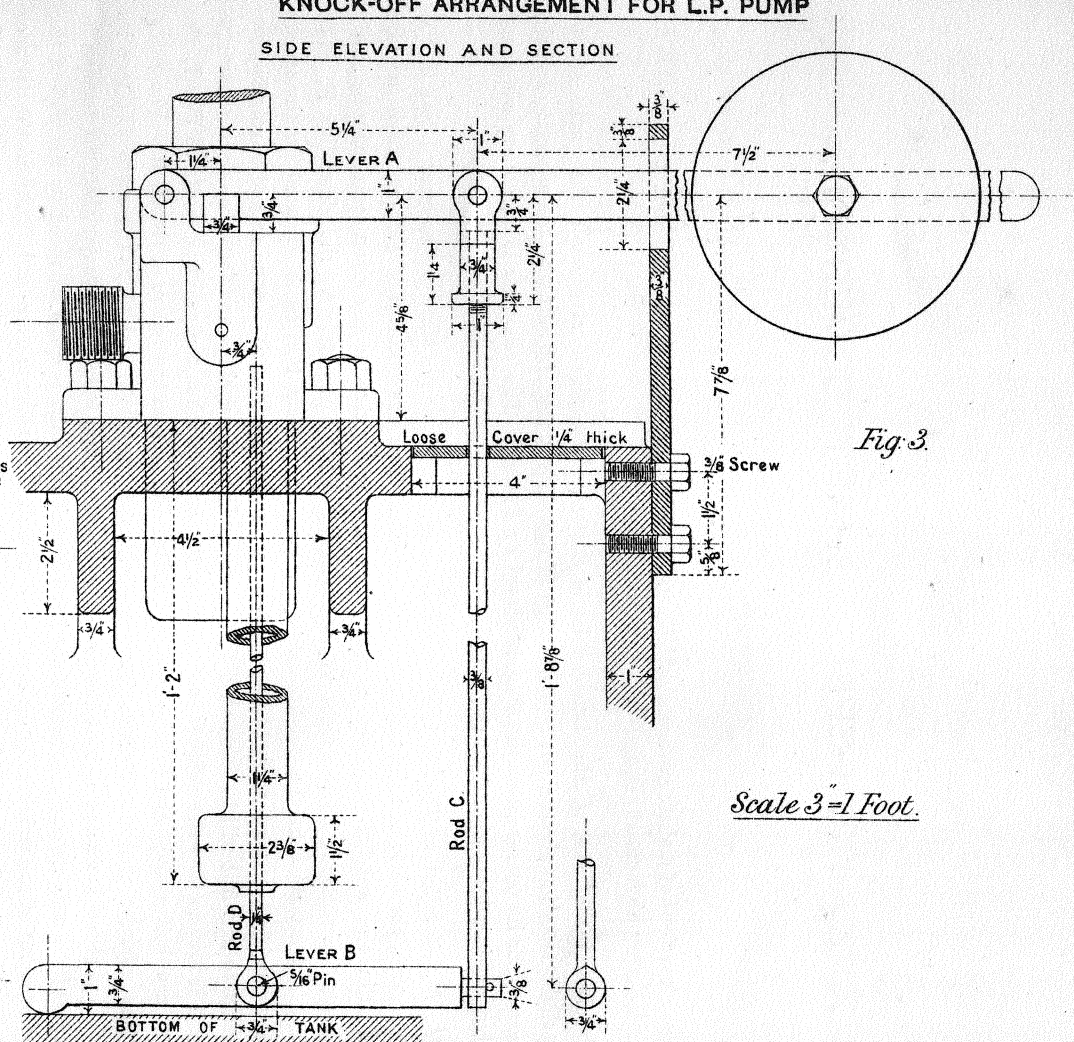
DETAILS OF TANK.

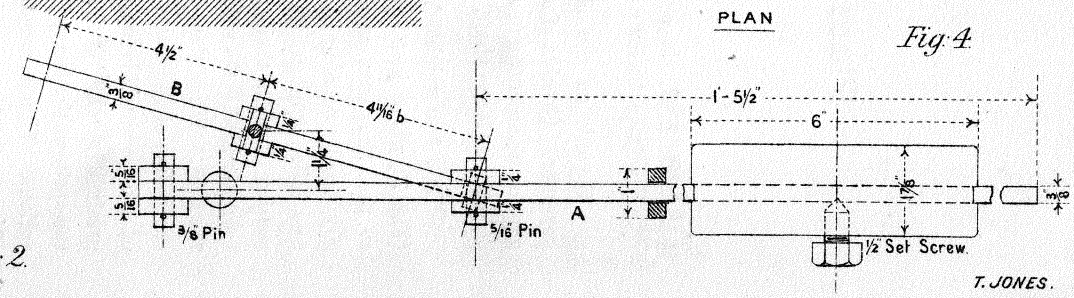




KNOCK-OFF ARRANGEMENT FOR L.P. PUMP

SIDE ELEVATION AND SECTION





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T.G. JONES.

Plate XXX.—HIGH-SPEED SHAFT GOVERNOR.

FIGS. 1, 2, show two elevations of a shaft governor which acts directly on the travel of a balanced piston valve for a two-cylinder single-acting high-speed engine.

Shrunk on the circular arm of one of the two cranks is a steel plate which carries all the parts of the governor. Capable of a slight vibration about a pin near the edge of the plate is the arm cast with the eccentric, and the gap in the eccentric necessary for its passage over the shaft is closed by a block. The eccentric is in no way connected directly with the shaft, but receives its motion from the plate.

The two weights W_1, W_2—detailed in Figs. 3, 4, respectively—are centred on the plate and connected by a link L (Fig. 7), which just fits between the plate and the facings on the weights. The enlarged end of each weight is recessed so that the mass of metal in the weights necessary to make the governor effective for any given speed may be nicely adjusted by running lead into the recesses. The weight W_1 is connected with the eccentric by the short link F. The two coiled springs, S_1, S_2, are attached to the weights as shown, and, when their tension is adjusted by the screws passing through their outer ends, they serve to hold the weights against the shaft until a certain speed of rotation has been attained. On reference to Fig. 5 it will be seen that the brass ends of the springs are shaped so as to screw into the coils. When the speed is low, so that the weights are inactive, the eccentric has the position shown in Fig. 1, the centre-line of the eccentric arm being tangential to a circle of $1\frac{1}{4}''$ radius drawn from the centre of the shaft. The centre of the eccentric is now the greatest possible distance from the centre of the shaft, and hence the valve will have its greatest travel. When the speed has increased so that the centrifugal force of the weights is greater than the tension in the springs, the heavy ends of the weights move outwards until the centrifugal force is again balanced by the pull of the springs. This outward movement of the weights causes the link F to pull the eccentric over and diminish the distance of its centre from the shaft: the resulting diminution of the valve travel and the change of the angular position of the eccentric alters the steam distribution, and diminishes the power developed in the cylinder; consequently the speed decreases. The outward motion of the weights is limited by the pins, P_1, P_2, screwed into the plate outside the weights.

The action of the governor is very rapid, and the standard for testing is 2 per cent variation from the mean speed when the full load is suddenly thrown off and on. All the parts of the engine are enclosed, and the engine case is filled with oil up to the level of the shaft, so that the governor runs in a bath of oil, and is consequently equally sensitive at all times.

EXERCISES.

1. **Governor Weights, W_1, W_2.** Draw the two elevations of each governor weight as given in Figs. 3, 4, and add a plan. *Scale $\frac{1}{2}$ full size.*

*2. **Shaft Governor, Complete.** Draw the two given elevations and add a plan, projected from the front elevation, showing the springs. *Scale $\frac{3}{8}$ full size.*

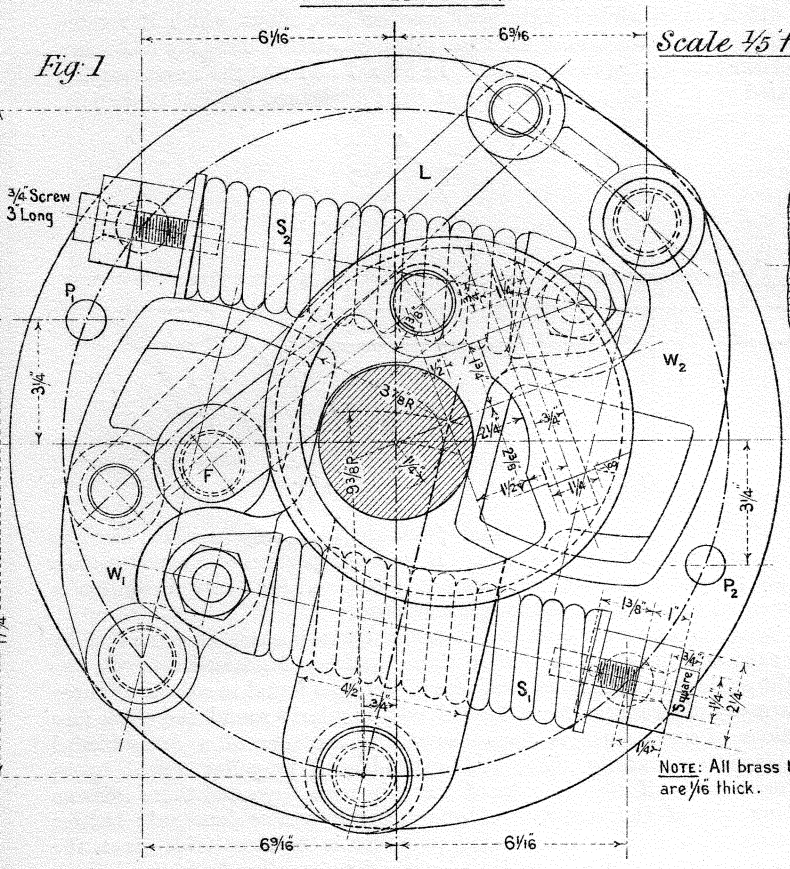
*This Exercise is intended for Advanced Students.

HIGH SPEED SHAFT GOVERNOR.

FRONT ELEVATION

Fig. 1

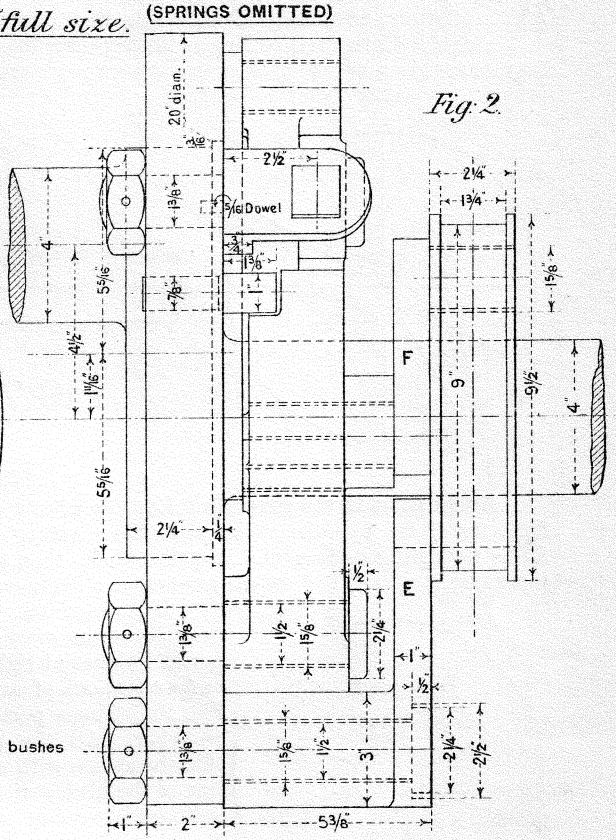
Scale ½ full size.



SIDE ELEVATION

(SPRINGS OMITTED)

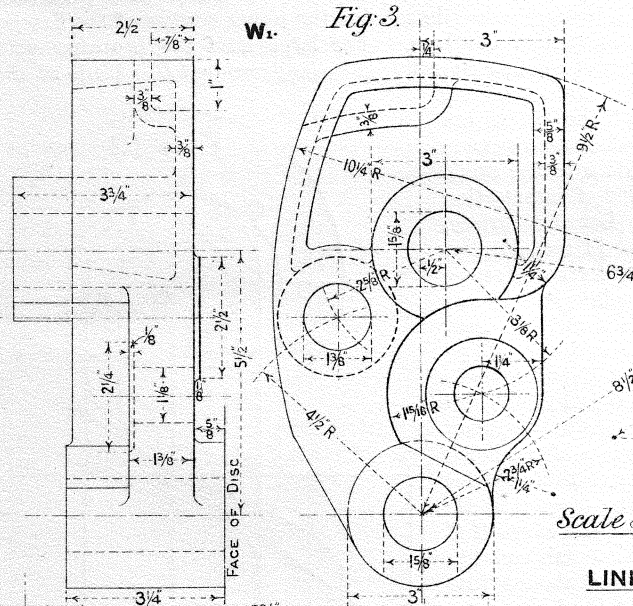
Fig. 2.



GOVERNOR WEIGHTS.

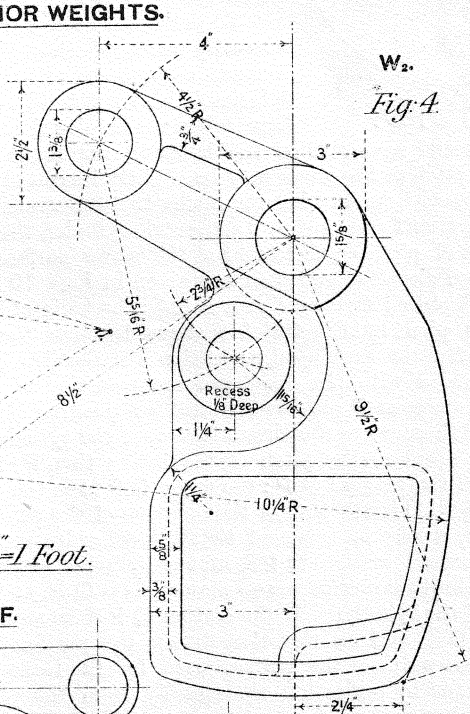
W1.

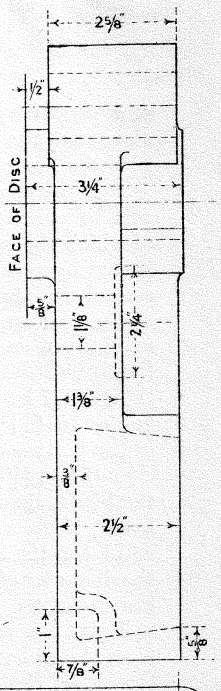
Fig. 3.



W2.

Fig. 4.





Scale 3"=1 Foot.

LINK F.

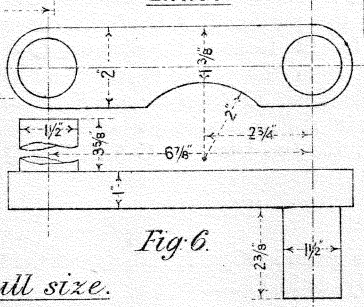
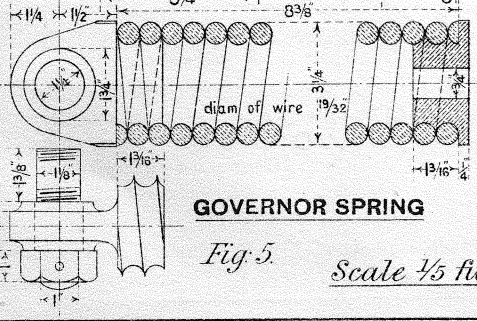


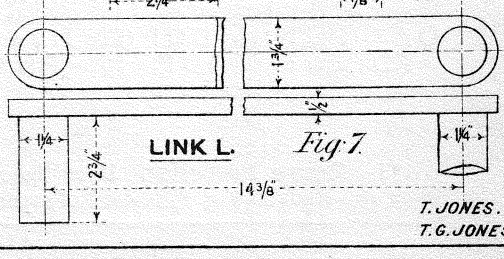
Fig. 6.



GOVERNOR SPRING

Fig. 5.

Scale ½ full size.



LINK L.

Fig. 7.

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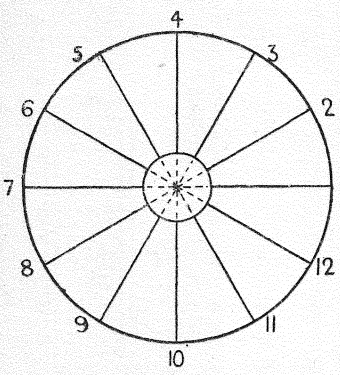
Plate XXXI.—SCREW PROPELLER.

A SCREW SURFACE is generated by a line which makes a fixed angle with another line, about which it rotates uniformly, advancing at the same time uniformly in the direction of the axis. The generating line may make any angle with the axis so long as the angle remains constant during the rotation. In Figs 7 and 8 of the accompanying diagram are given drawings of screw surfaces as generated by a line when respectively at right angles and inclined to the axis.



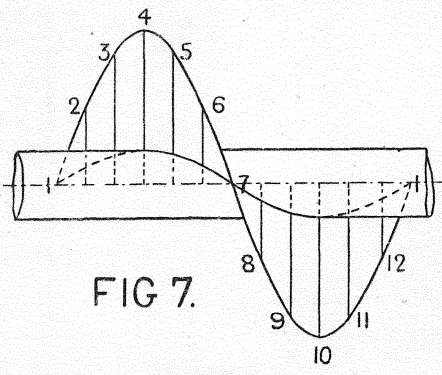


FIG 7.

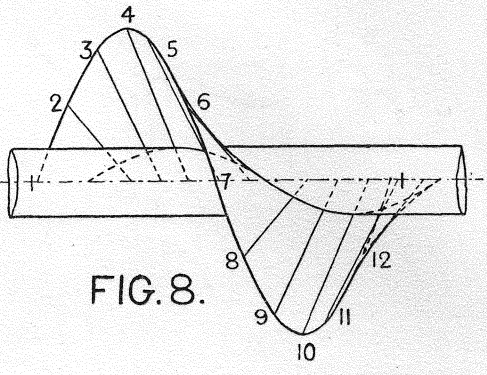


FIG. 8.

Every point in the generating line describes a cylindrical helix of the same pitch as the screw surface, but the diameter of the cylinder varies with the distance of the point from the axis. If a small portion of a screw surface forms the acting surface of a propeller blade, then the propeller would be of constant pitch, and for every revolution in the water it would, theoretically, advance a distance equal to the pitch of the screw surface.

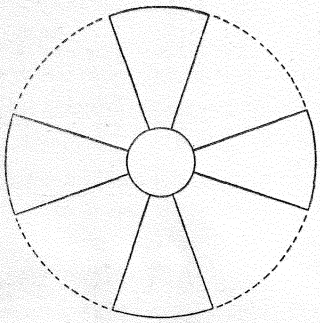


FIG. 9.

If three or four separate screw surfaces at a constant distance apart be generated by lines about the same axis, and the short portion of these surfaces contained between two parallel planes at right angles to the axis be considered, it will be found to consist of three or four portions of as many different surfaces spaced out regularly round the circle (see Fig. 9). These portions of screw surfaces form the acting surfaces of a many-bladed propeller. All the blades are exactly alike, and a two-bladed propeller would be as efficient as one with more blades if the draught of the ship were large and there were no fear of the blades rising out of the water, or of one being broken or damaged; but for ordinary sea-going purposes a three or four-bladed propeller is most suitable since the blades will have as large an area in contact with the water for a smaller diameter.

To prevent a useless churning of the water near the centre of the propeller, the boss is usually made spherical, and if the blades are detachable the upper surface of the flanges is made continuous with the surface of the boss. For large sizes the propeller with detachable blades is to be preferred to one cast solid, since any accident to a blade of the former does not involve the expense of an entirely new propeller, and again, since the holes in the flanges of the blades are elongated, the pitch of the screw may be slightly increased or decreased so as to give the best results, by turning the blades to a different angle with the axis.

If the screw surface is cut by a concentric cylinder, the line of intersection will be a helix of pitch equal to that of the screw surface. Let the surface, of which the end elevation and plan are given in Figs. 10 and 11 respectively, be cut by a cylindrical surface of radius O A: the helix of intersection is represented in the plan by the full-line curve through the point P. If the cylindrical surface be developed, the helix will develop into a straight line, making an angle a with the developed cross section of the cylinder. The tangent to the curve at P may be obtained by drawing G P at right angles to the axis, of length equal to the circumference of the cylinder, and G H at right angles to G P equal to the pitch of the helix; then P H is the development of the helix and the tangent at P: the angle G P H is the angle a of the helix.

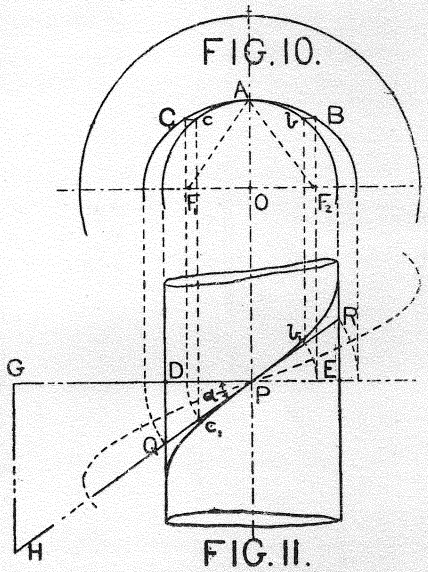


FIG. 10.

FIG. 11.

If $b_1 c_1$ (Fig. 11) is the plan of that portion of the circular section used for the blade, then, it may be assumed that $b_1 c_1$ coincides with the tangent at P: hence, if the vertical section Q P R of the cylinder be taken, the curve B C will lie on the elliptical section whose major axis is Q R, and minor axis equal to the diameter of the cylinder. If the section Q P R be now turned about P into the direction D E, and an elevation drawn, the portion C A B of the curve will give the real width of the surface used for the blade at the distance O A from the axis; and by projecting horizontally from the points C and B on to the circle, the elevation $c\,b$ of the section is obtained. *To find the foci* F_1, F_2 *of the ellipse*: Comparing the two triangles O A F_1 (Fig. 10) and D Q P (Fig. 11), we have A F_1 = semi-major axis of ellipse = Q P, and O A = radius of cylinder = P D; also angle A O F_1 = 90° = P D Q, ∴ the two triangles O A F, P D Q are equal; ∴ O F_1 = D Q. Now, since

[*Continued on next page.*

EXERCISE.

*1. **Screw Propeller.** Draw the views given in Figs. 1, 2, 3, 4, and the blade sections of Fig. 6. *Scale* $\frac{3}{4}$″ = 1 *foot.* Show the studs in Fig. 2, instead of separately, as in Fig. 5.

* This Exercise is intended for Advanced Students.

SCREW PROPELLER WITH DETACHABLE BLADES.

ELEVATION AND SECTION
WITH DEVELOPMENT OF BLADE.

Scale 3/8" = 1 Foot.

Diam. of Propeller 22'-2 3/4"
Pitch " " 34-9 3/4"

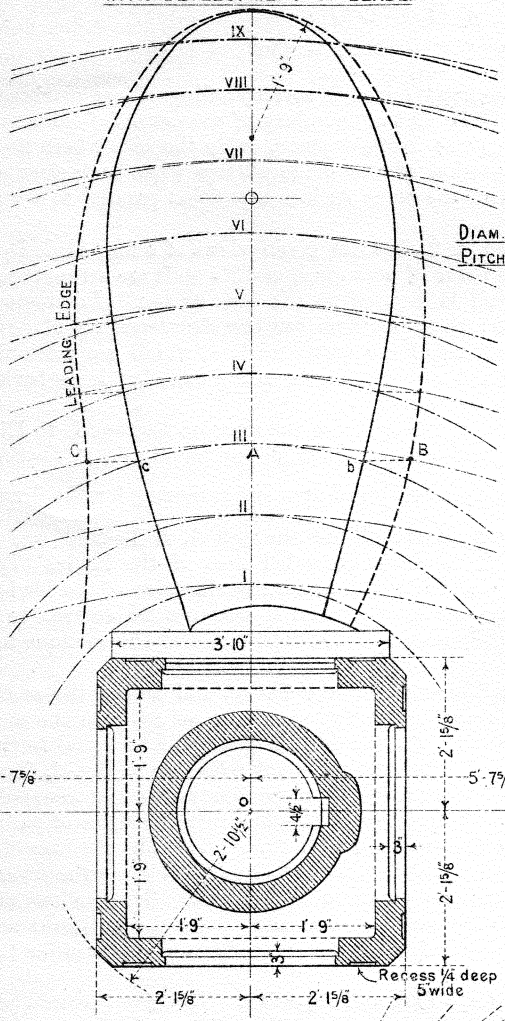
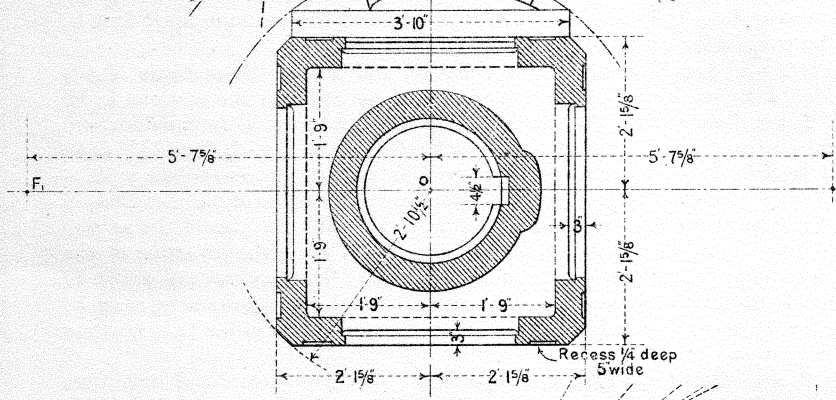


Fig. 1



SIDE ELEVATION AND SECTION

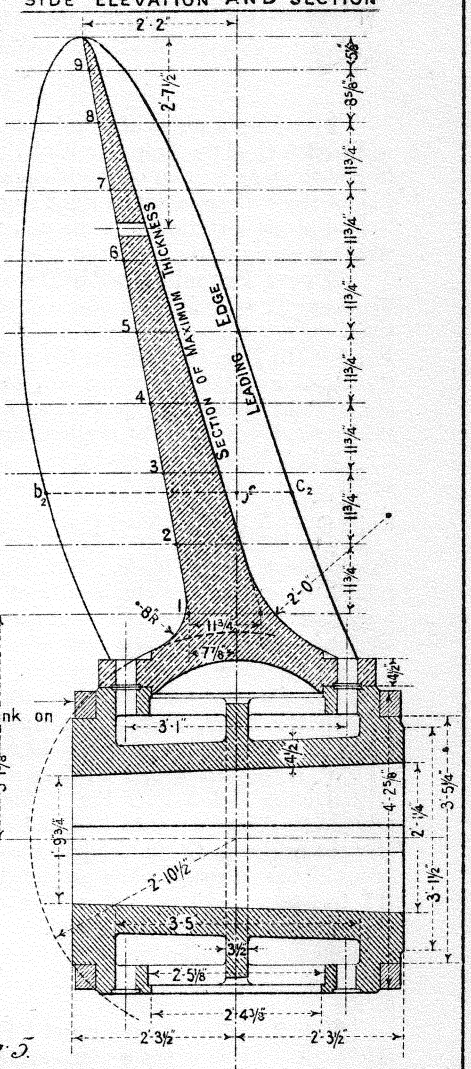
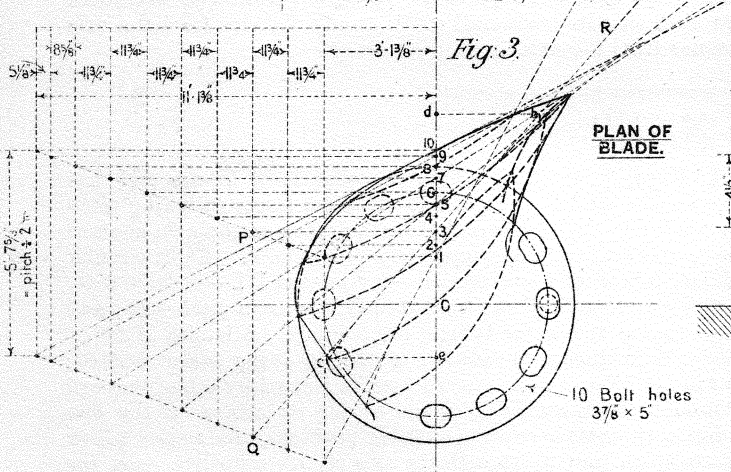


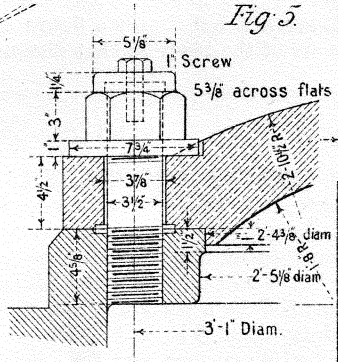
Fig. 2.

Fig. 3.



PLAN OF BLADE.

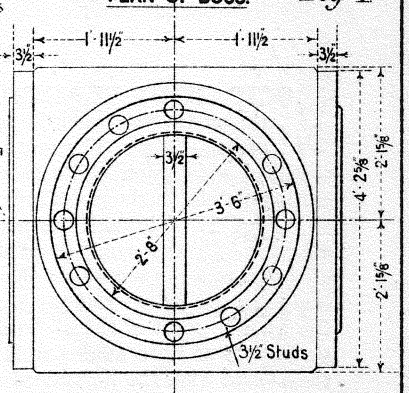
Fig. 5.



DETAIL OF STUD FOR BLADES.

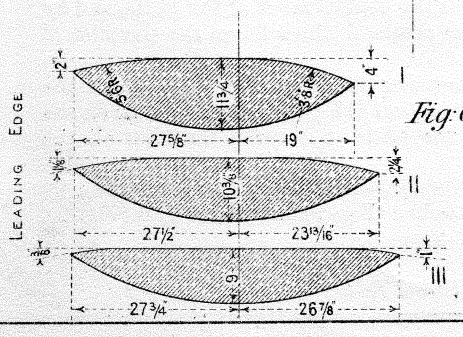
PLAN OF BOSS.

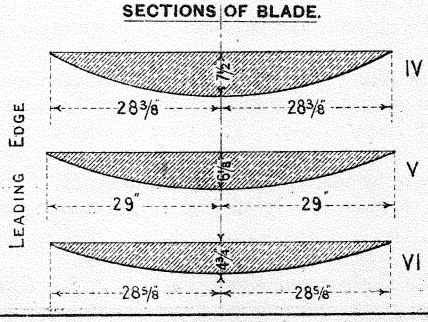
Fig. 4

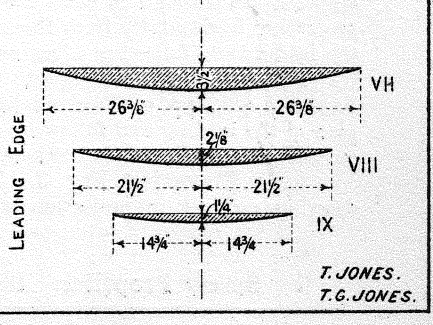


SECTIONS OF BLADE.

Fig. 6.







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the triangles P G H and P D Q are similar $\frac{PG}{PD} = \frac{GH}{DQ}$, and since P G = 2π × radius of cylinder = $2\pi \cdot$ P D.

$$\frac{PG}{PD} = \frac{2\pi \cdot PD}{PD}, \text{ and } \frac{GH}{DQ} = \frac{\text{pitch}}{DQ}$$

$$\therefore \frac{2\pi \cdot PD}{PD} = \frac{\text{pitch}}{DQ}, \therefore DQ = \frac{\text{pitch}}{2\pi} = OF_1.$$

By taking a series of circular sections of the screw surface, and on each corresponding ellipse marking the actual width B A C of the propeller blade, the several points B, C, will lie on the boundary of the *expanded blade area*, a figure in which every portion of the blade surface is turned into the same vertical plane, or, in the case where the generating line of the surface is not at right angles with the axis, the projection of the blade surface when each circular section is turned about a vertical axis through the point corresponding with the point A, into a position parallel to a vertical plane which is at right angles to the axis

Screw Propeller with Detachable Blades. In Figs. 1, 2, 3, 4 are given views of a four-bladed propeller, of diameter $22' - 2\frac{3}{4}''$, and uniform pitch $34' - 9\frac{3}{4}''$. The boss is made of cast steel, and its ends are strengthened by steel rings shrunk on. The blades are of manganese bronze, and each is secured to the boss by ten $3\frac{1}{2}''$ diameter studs (see Fig 5). In **Fig. 6** are given ten circular sections of the blade: these sections are the developed circular sections, *i.e.*, the circular sections flattened out, and on this account the sections of the screw surface, which are portions of helices, are straight lines. The generating line of the screw surface is not at right angles to the axis, but leans backwards from the vertical centre line of the boss by a distance of $2' - 2''$ at its outer end.

When drawing the blade, proceed as follows: **Fig 1.** Draw the arcs for the circular sections I. to IX. inclusive, and through their points of intersection with the vertical centre-line draw portions of ellipses having F_1, F_2 for their common foci $\left(OF_1 = OF_2 = 5' - 7\frac{5}{8}'' = \frac{\text{pitch}}{2\pi}\right)$. As explained before, these elliptical arcs are necessary for the drawing of the development of the blade. Referring to section III., mark off on the ellipse through A, A C = $27\frac{3}{4}''$ and A B = $26\frac{7}{8}''$ (these dimensions are obtained from III., Fig. 6); then B and C lie on the expanded area of the blade. These points projected horizontally to the circle through A give points c and b, which lie on the elevation of the blade. For the sections I., II., since the edges of the acting face are rounded off considerably, it will not be correct to obtain the elevation of their ends by projecting from the corresponding points on the development, but the sections must first be drawn in the plan, and the points then obtained by projection.

In the **Plan, Fig 3**, the tip of the blade is $2' - 2''$ from the centre of the flange, and before the sections of the blade may be drawn, the line O 10 must be divided into parts proportional to the distances between the sections I., II. . . . . If the line 1, 2, . . . 9 be drawn in Fig. 2, the distances O_1, O_2, &c. in the plan will be equal to the distances of the points 1, 2, 3 . . . Fig. 2, from the vertical centre-line; or, proceeding without reference to Fig. 2, $O_1 = 7\frac{7}{8}''$, O 10 = $2' - 2''$; through points 10 and 1 draw lines of lengths $11' - 1\frac{3}{8}''$ and $3' - 1\frac{3}{8}''$ respectively—to any convenient scale—at right angles to O 10, and join their extremities; the points of intersection of this line with the series of parallel lines of given distances apart, when projected to the line O 10, give the required points 2, 3 . . . 9. The position of the section III. is determined by drawing 3 P and P Q to the given dimensions, and then the line Q 3 R gives the direction of the straight portion of the section which is now drawn to the dimensions given in III., Fig. 6. The sections are drawn as though they were horizontal sections, since their slight downward curvature, as seen from the elliptical arcs, may be neglected. The distances O d, O e, of the extremities b_1, c_1 respectively from the centre-line are required for the elevation in Fig. 2.

Fig. 2. Project from c and b Fig. 1 to Fig. 2, and make f b_2 = O d, and f c_2 = O e. The given section of maximum thickness of blade is not a plane section, but simply a figure such that its horizontal width at any distance from the axis is equal to the maximum thickness of the blade at that distance from the axis.

Plate XXXII.

SOLID FOUR-BLADED SCREW PROPELLER, Figs. 1, 2, 3, 4. This propeller is of bronze and has the blades cast with the boss; it is $15' - 1''$ diameter, and has a leading pitch of $20' - 4''$ and a larger following pitch of $22' - 11\frac{5}{8}''$. The method adopted for its representation differs slightly from that for the other example on account of the double pitch and the consequent difficulty of drawing the blade sections separately as in Fig. 4. Eight circular sections of the blade are taken, but it will be sufficient to describe how only one section—say section III.—is dealt with.

Fig. 1. Through the point S draw a portion of the ellipse having F, F as foci, where O F = mean pitch ÷ 2π; and also through the same point draw lines S P_1 and S P_2, producing the latter beyond the point S. A length of $22\frac{11}{16}''$ of S P_1 forms the section of the *leading* surface, and $18\frac{1}{4}''$ on P_2 S produced, the section of the *following* screw surface: complete the drawing of the section to the dimensions given in III., Fig. 4; the curved back is formed by a line through the leading point of the section and a circular arc passing through the following point and having its centre on the line through S at right angles to S P_2. The blade sections so drawn show their relative angular positions, the angles which they make with the horizontal centre-line being equal to those which they make with the axis of the propeller. On the elliptical arc through S, mark the points A and B as shown, these points will lie on the development of the blade, and by projecting horizontally from them to the circular arc through S, the points a, b are obtained which lie on the elevation of the leading and following edges respectively.

Plan, Fig. 2. The length of the line O 8 is $14\frac{3}{8}''$, the droop of the generating line (see **Fig. 3**). Draw the lines 3 q, q p_1, q p_2 to the given dimensions and on the lines p_1 3 and p_2 3 r draw the section III.; the points a_1, b_1 lie on the plan of the leading and following edges respectively. The plan of the back of the blade is a curve touching all the curved parts of the blade sections.

Side Elevation, Fig. 3. The elevations a_2, b_2 of the ends A, B of the circular section No. III. are obtained by drawing $e\,a_2$, $f\,b_2$ in projection with a, b respectively of Fig. 1, and making $e\,a_2$ = O c (Fig. 2) and $f\,b_2$ = O d (Fig. 2).

EXERCISE.

*1. **Screw Propeller.** Draw the three given views, Figs. 1, 2, 3. *Scale* 1″ = 1 *foot.*

*This Exercise is intended for Advanced Students.

SOLID FOUR-BLADED SCREW PROPELLER.

Scale 1/2" = 1 Foot.

DEVELOPMENT AND END ELEVATION OF ONE BLADE.

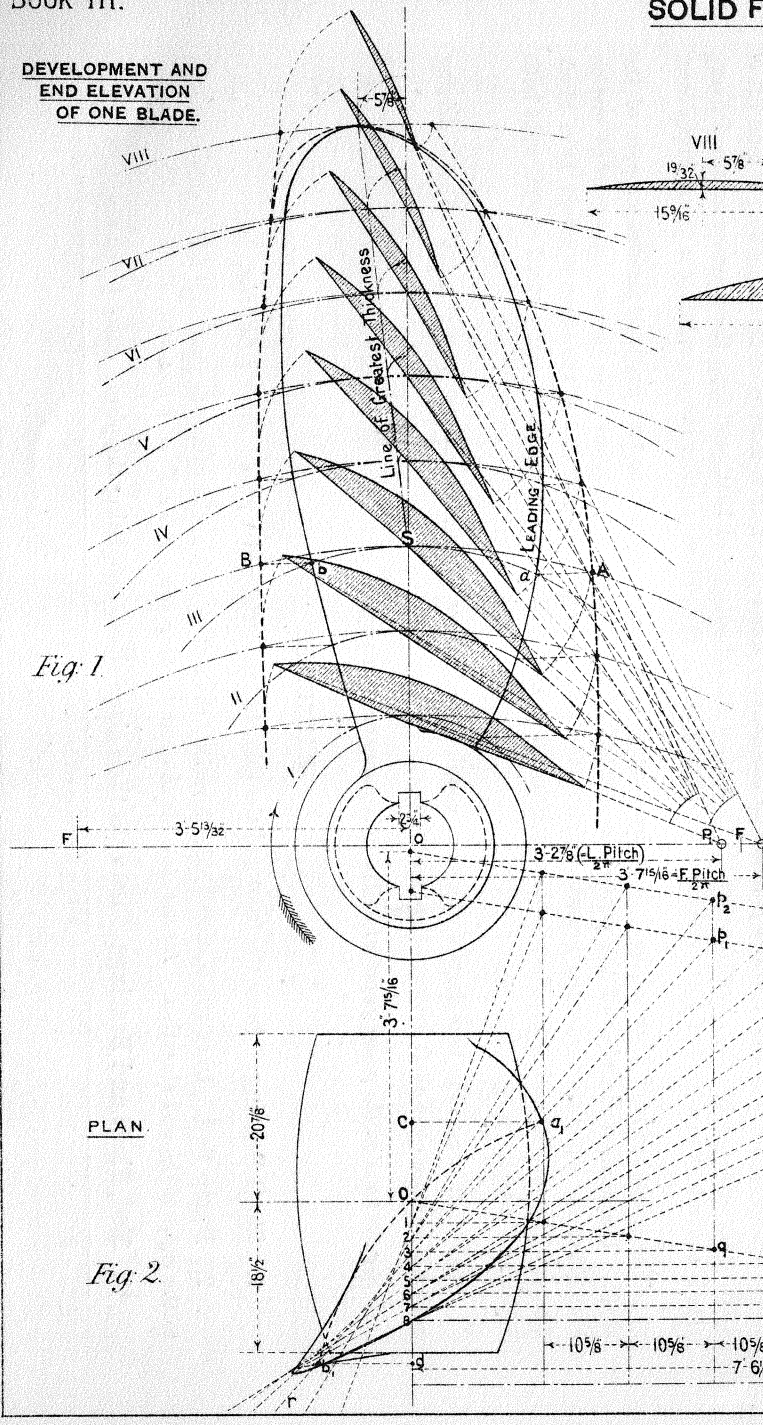

Fig. 1

Fig. 2

SECTIONS OF BLADE.

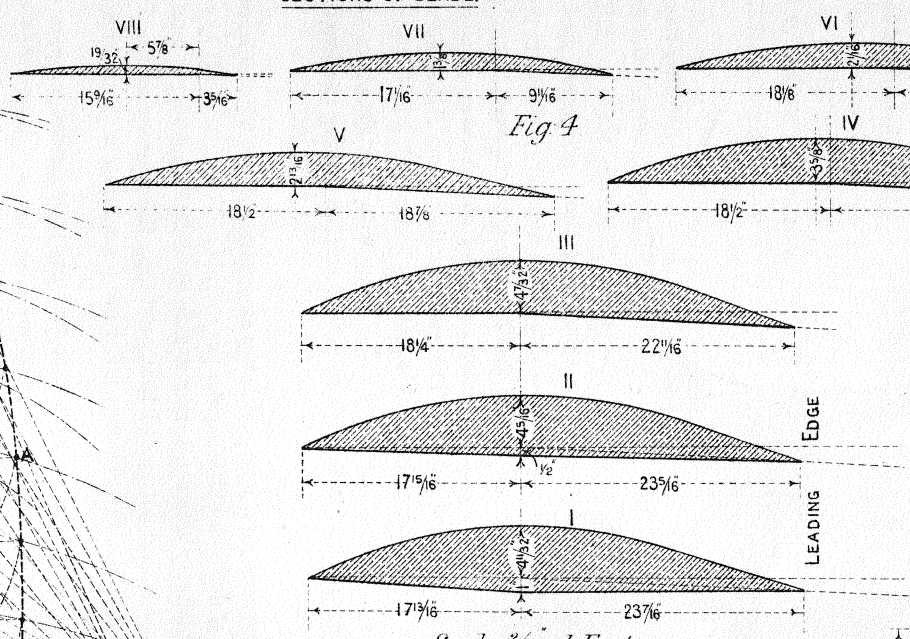

Fig. 4

Scale 3/4" = 1 Foot.

SIDE ELEVATION

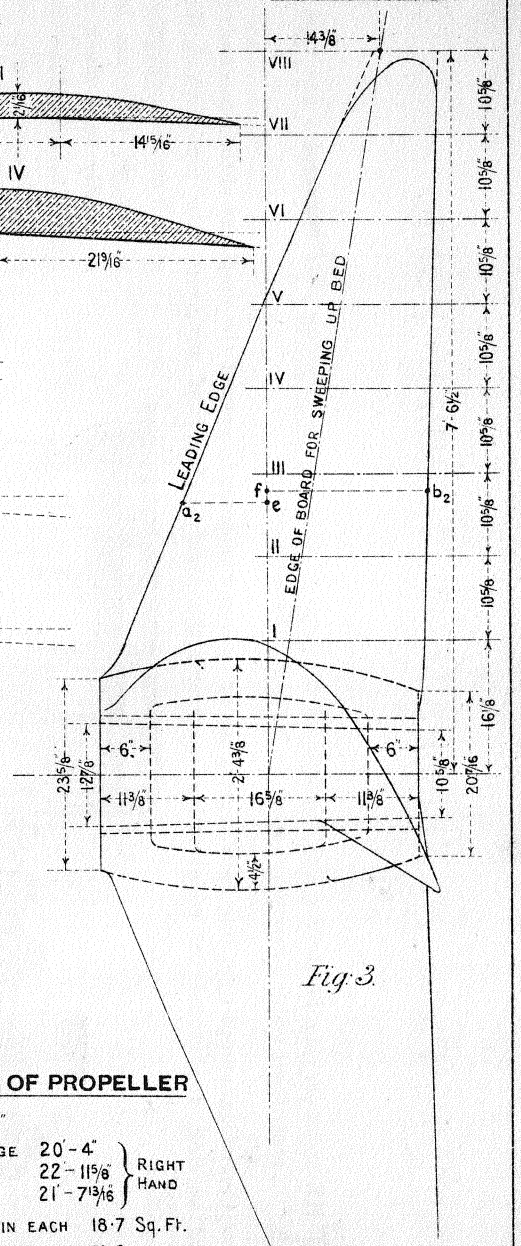

Fig. 3

PARTICULARS OF PROPELLER

DIAMETER.		15'-1"	
PITCH.	LEADING EDGE	20'-4"	RIGHT HAND
"	FOLLOWING "	22'-11 5/8"	RIGHT HAND
"	MEAN	21'-7 13/16"	RIGHT HAND
4 BLADES.	SURFACE IN EACH	18·7 Sq. Ft.	
	TOTAL PROJECTED AREA	53·2 " "	

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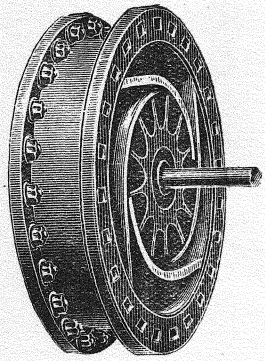
Plate XXXIV.—PATENT TURBINE PUMP.

DETAILS OF PUMP AND WHEEL. The pump has two chambers, in each of which rotates a wheel with thirteen radial vanes. The first chamber is bolted to the suction chamber at the end of the bed by sixteen $\frac{5}{8}$″ bolts, and to the outside face of the second chamber, the delivery chamber is bolted.

The face Y of the first pump chamber (Fig. 3), which is bolted against the suction chamber, has four pairs of ports, P, P, and each pair opens out into a sector-shaped space, terminated at the sides by radial webs, B, B, at right angles to each other. The water, being drawn up the suction pipe and into the suction chamber by the rotation of the wheel, enters the first pump chamber by the ports P, and is guided towards the centre, where it enters the rapidly rotating wheel. Discharged from the circumference of the first wheel, the water is led away in four distinct streams by the four curved guides on the side X of the chamber shown in Fig. 2, and the accompanying illustration. The water flows outwards between the guides and enters the second chamber by the ports P, P, where it is dealt with as in the first chamber, receiving from the second wheel an additional amount of energy. The water enters the delivery chamber by ports on its face like those in the face Y of the pump chamber.



As will be seen from the details of the wheel in Fig. 6, the portions of the vanes which move across the inlet to the wheel have edges curved forward, so that the water may enter the wheel without shock; and when in the wheel, the change in the direction of the water is facilitated by the curved boss. Each wheel is keyed to the shaft, and each chamber provides a support for the shaft in the internal brass-bushed boss projecting from the face Y. The end of the shaft is carried in a brass-bushed hole through the delivery chamber.

Attention is directed to the method of drawing the curved guides in Figs. 2 and 5. Referring to Fig. 2, the left-hand guide, which has its end on the vertical centre line, may be drawn as follows:—The inner curve is $5\frac{1}{2}$″ radius and has its centre on the vertical centre-line and on the circumference of a circle 2″ diameter, concentric with the wheel; the straight portion of the inside of the guide is a line tangential to the curve, and meeting the inner circumference of the chamber in a point $4\frac{3}{4}$″ from the highest point. The outside curve is $5\frac{15}{16}$″ radius, with its centre on a circle $2\frac{3}{16}$″ diameter as shown, and the end of the guide is formed by a curve of 1″ radius.

Power required to drive the Pump. The pump lifts 240 gallons of water per minute through a height of 50 ft.,

$$\therefore \text{ net H.P.} = \frac{240 \times 10 \times 60}{33{,}000} = 4\tfrac{4}{11} \text{ H.P.}$$

Assuming an efficiency of 50 per cent.

$$\textbf{Actual H.P.} = \frac{4\frac{4}{11}}{\text{efficiency}} = 4\tfrac{4}{11} \times \frac{100}{50} = 8\tfrac{8}{11} \textbf{ H.P.}$$

The 6″ diameter driving pulley makes 1100 revolutions per minute,

$$\therefore \text{ velocity of belt} = \frac{6}{12} \times \frac{22}{7} \times \frac{1100}{1} = 1728{\cdot}5 \text{ ft. per minute.}$$

For this speed a belt about 3″ wide will transmit the above horse-power.

EXERCISES.

1. **Pump Chamber.** Draw elevations of the two faces X, Y of one chamber (Figs. 2 and 3), the sectional elevation as in Fig. 1, and the plan projected from either side elevation. *Scale $\frac{1}{2}$ full size.*

2. **Delivery Chamber.** Draw the two side elevations, the sectional elevation and the plan, the last projected from a side elevation. *Scale $\frac{1}{2}$ full size.*

N.B.—The face in contact with the pump chamber will have four ports P like the face Y of the latter, but since there are no ribs A, B, each port will be continuous and not in two portions.

3. **Wheel, Fig. 6.** Draw a complete front elevation (Fig. 6, completed), a sectional front and a sectional side elevation. *Scale full size.*

*4. **Pump Chambers and Wheel.** Draw Figs. 1, 2, 3, 5. *Scale $\frac{1}{3}$ full size.*

*5. **Complete Pump.** Draw the side elevation and section—showing the chambers in section, as in Fig. 1, and the bed as on Plate XXXIII.—the end elevation to the right of the side elevation, the plan projected from the side elevation, and the sectional elevation at C D, Fig. 5, projected from the plan to the right. *Scale 3″ = 1 foot.*

*These Exercises are intended for Advanced Students.

9" MATHER–REYNOLDS PATENT TURBINE PUMP.

DETAILS OF PUMP CHAMBERS AND WHEELS

ELEVATION OF FACE X OF CHAMBER.

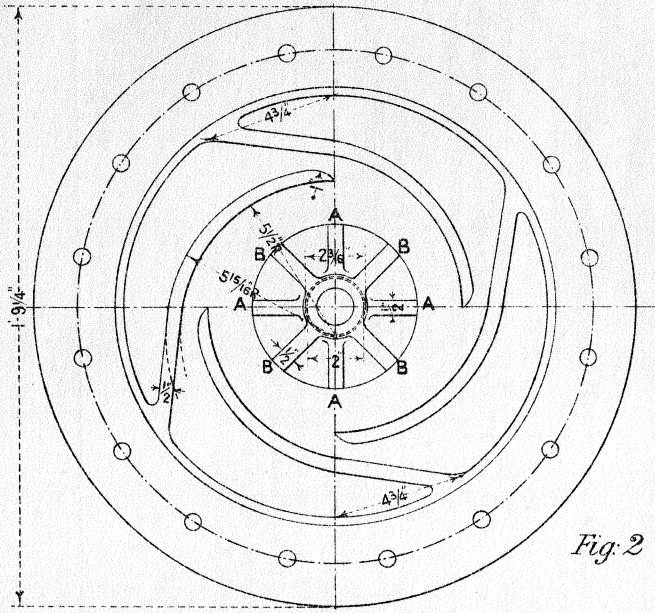


Fig. 2

SECTIONAL ELEVATION

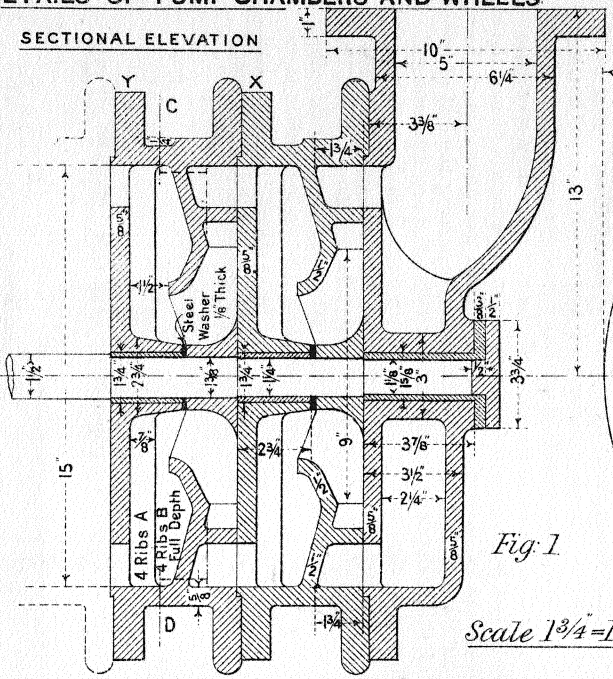


Fig. 1

Scale 1¾"=1 Foot

ELEVATION OF FACE Y OF CHAMBER.

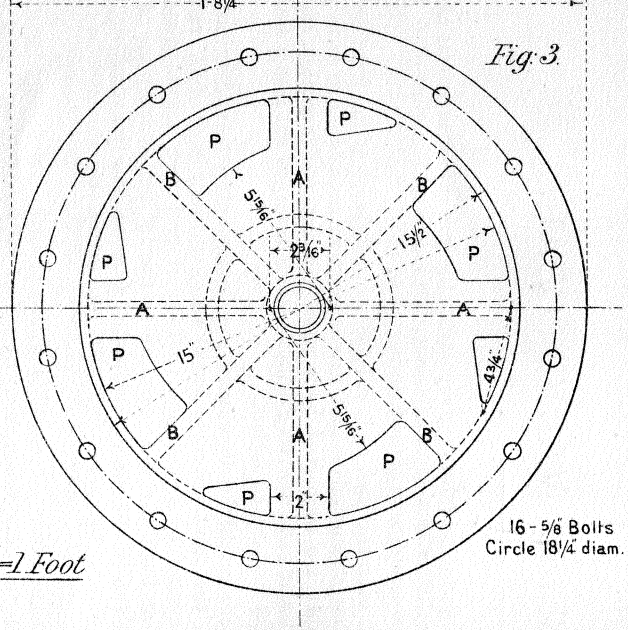


Fig. 3

16 - ⅝ Bolts
Circle 18¼" diam.

DETAILS OF WHEEL.

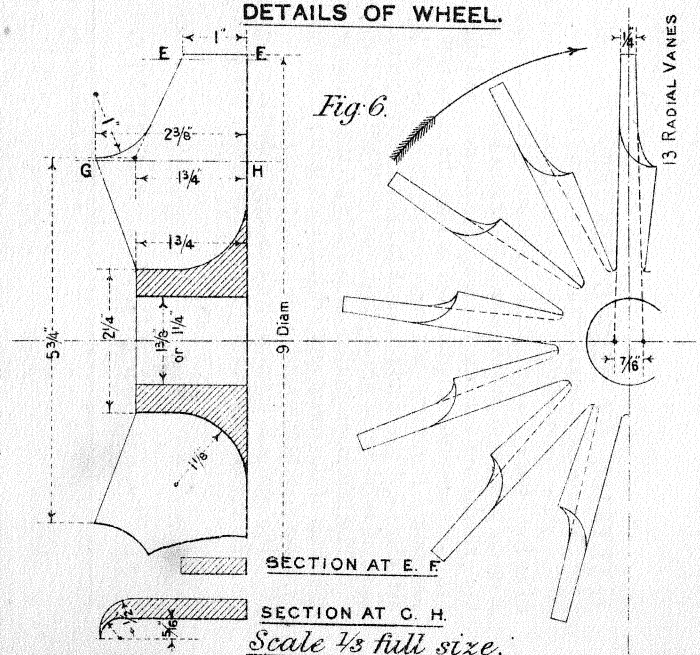


Fig. 6.

Scale ⅓ full size.

PLAN.

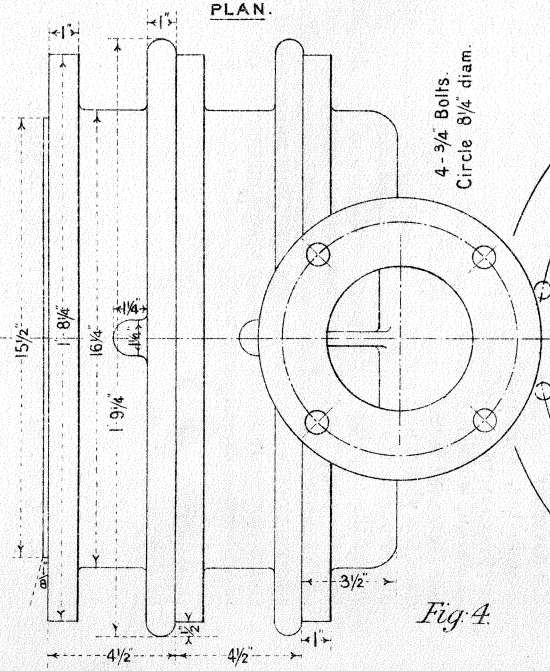


Fig. 4.

SECTIONAL ELEVATION AT C. D.

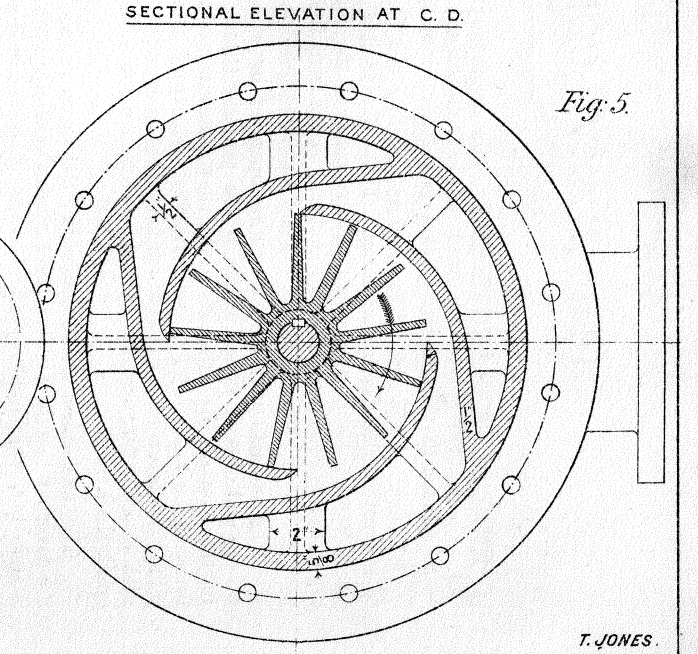


Fig. 5.

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Plate XXXV.—CORLISS VALVE GEAR.

GENERAL ARRANGEMENT. The accompanying coloured drawing represents the general arrangement of the Corliss Valve Gear as fitted on the high-pressure cylinder of a triple-expansion horizontal mill engine of 6 feet stroke: the frontispiece gives a good general idea of a complete engine of similar type.

The cylinder is secured to the foundation by the foot near the back end, and the vertical flange at the front serves to connect it with the engine frame. The cylinder has two steam valves and two exhaust valves, placed so as to give the shortest possible passages: the valve boxes of the former are connected by a passage of rectangular section, on the top of the cylinder, into which the steam passes from the boiler; and the two exhaust valve boxes open out into a similar passage below, from which the exhaust steam escapes by the rectangular outlet.

The two sets of circular valves are operated by separate eccentrics to ensure the best possible steam distribution. On the end of each valve spindle, which projects through the front cover, is keyed a wrought-iron lever of $4\frac{1}{2}''$ radius. In the case of the exhaust levers, they are connected together by a horizontal rod, equal in length to the distance between the valves, and they receive their vibratory motion from the rod attached to the $1\frac{3}{4}''$ pin on the front of the right hand lever. This rod, which actuates the exhaust valves, is not usually connected directly with the eccentric, but with an oscillating arm worked from an eccentric on a shaft near the steam cylinder, running at the same speed as the crank shaft.

The mechanism for the control of the steam valves is such that the cut-off is always prompt, and may be varied by the governor to suit the demands for work made upon the engine. The steam eccentric rod, of $4\frac{1}{2}''$ travel, is connected with a slide bar, supported by the bracket from the side of the cylinder: the slide bar carries two trip boxes with their tripping levers and pieces. The upper ends of the tripping levers are connected by short links with the segmental racks as shown, while their short arms are below the tripping pieces, so that for some positions of the slide bar they may raise the pieces. On each end of the supporting bracket for the slide bar is bolted a dash-pot cylinder, in which is placed the dash-pot piston and spring. The valve rod connects the steam valve with the piston, and from the other side of the piston passes the dash-pot spindle with a steel catch plate on its end. When the slide bar is nearing the end of its stroke the tripping pieces press on the top of the flat ends of the dash-pot spindles, and both spindles are disconnected from the slide bar and the steam valves closed; but just before it reaches the end, one tripping piece falls down in front of the catch plate, and on the return stroke engages with the catch plate, and drags along the spindle and dash-pot piston against the resistance of the spring. This movement of the dash-pot piston causes the steam valve to turn and open the steam port: but as the slide bar moves further in its stroke the levers attached to the trip box of the engaging tripping piece become more nearly vertical, and so gradually raise the trip piece; until, for some position, the trip piece disengages from the catch plate, and then the dash-pot spring forces back the piston, and the steam valve closes. It is evident that by altering the distance between the upper ends of the two sets of trip levers the liberation of the catch plate would be delayed or hastened, according as the distance is diminished or increased.

EXERCISE.

*1. **General Drawing of Corliss Gear.** Draw the three given views on paper of imperial size. *Scale* $2'' = 1$ *foot.*

Plate XXXVI.

DETAILS OF THE CYLINDER. The cylinder is 22″ diameter × 6′ stroke, with deep covers at the ends, each strengthened with six webs: the front cover carries the piston rod stuffing box, and also a relief valve. The valve boxes of the four circular valves are placed as near to the covers as possible, so as to give direct passages to or from the cylinder. The two steam valve boxes are placed on the top of the cylinder, as is usual, and connected by a steam passage of rectangular section into which the steam enters by the 8″ hole. The two exhaust valve boxes below the cylinder are connected in a similar manner, and the exhaust steam leaves by the rectangular outlet. Each valve box has two transverse internal ribs, so that the valve is supported in the box at four places along its length. The passage connecting the valve box with the cylinder has a length of $2' - 0\frac{1}{2}''$ at the box end, but it diminishes towards the cylinder; and the inside faces of the covers have curved recesses top and bottom so as not to obstruct the passages. The exhaust valve boxes are drained, and the right-hand one is also fitted with an escape valve.

The hollow projection on the side of the cylinder supports the slide bar and dash-pot bracket. The $2\frac{1}{2}''$ holes in the sides of the steam and exhaust chambers are connected by a pipe, so that, on starting the engine, the intermediate cylinder may be supplied with high-pressure steam by opening the valve on this pipe.

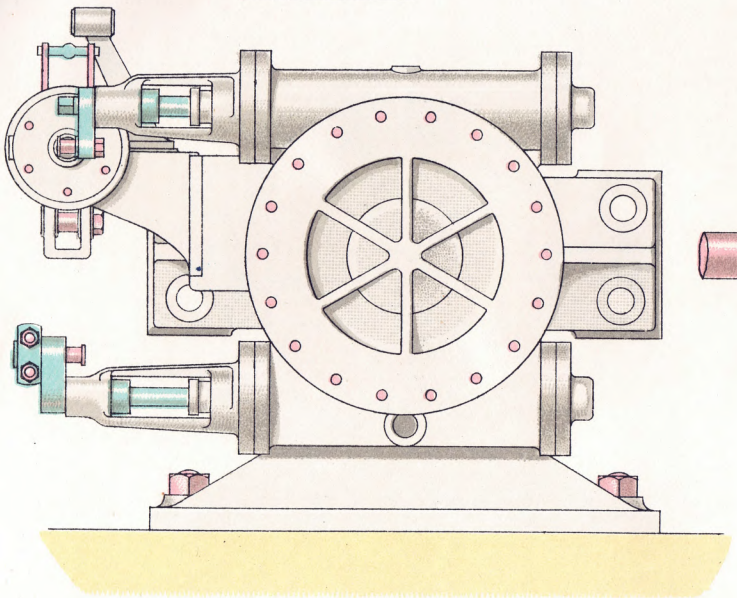
The piston is fitted with three simple packing rings, and is screwed to the conical end of the piston rod by a $3\frac{1}{2}''$ nut. To increase the bearing area of the piston the lower part is widened by $\frac{7}{8}''$ on each side.

EXERCISE.

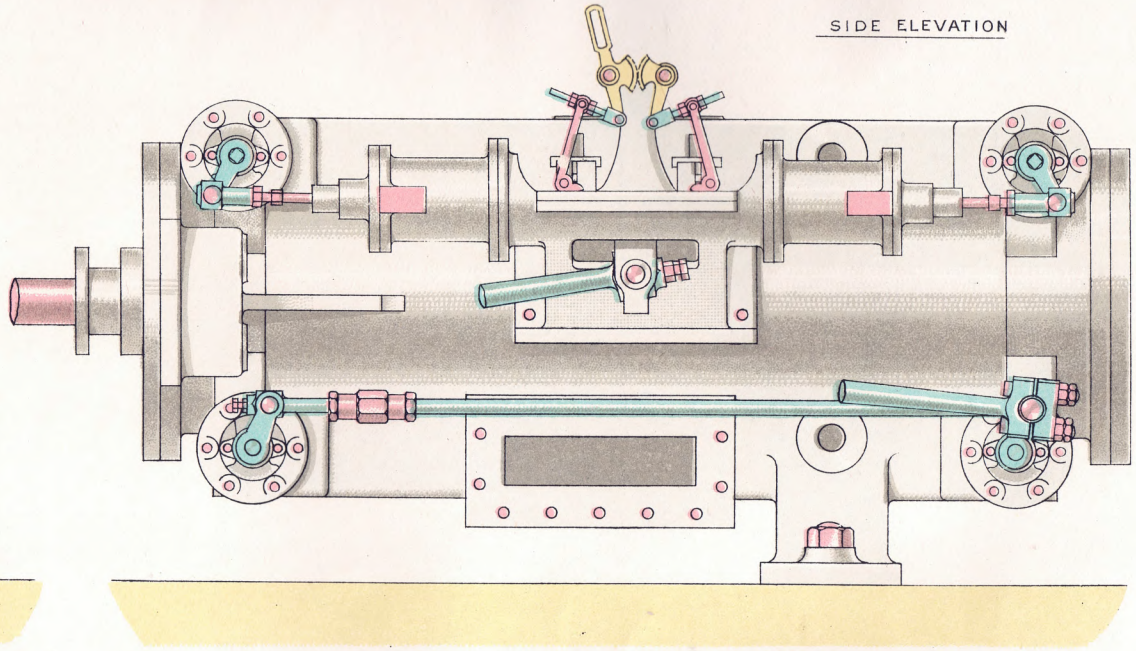
*1. Draw the four given views. *Scale* $1\frac{1}{2}'' = 1$ *foot.*

* These Exercises are intended for Advanced Students.

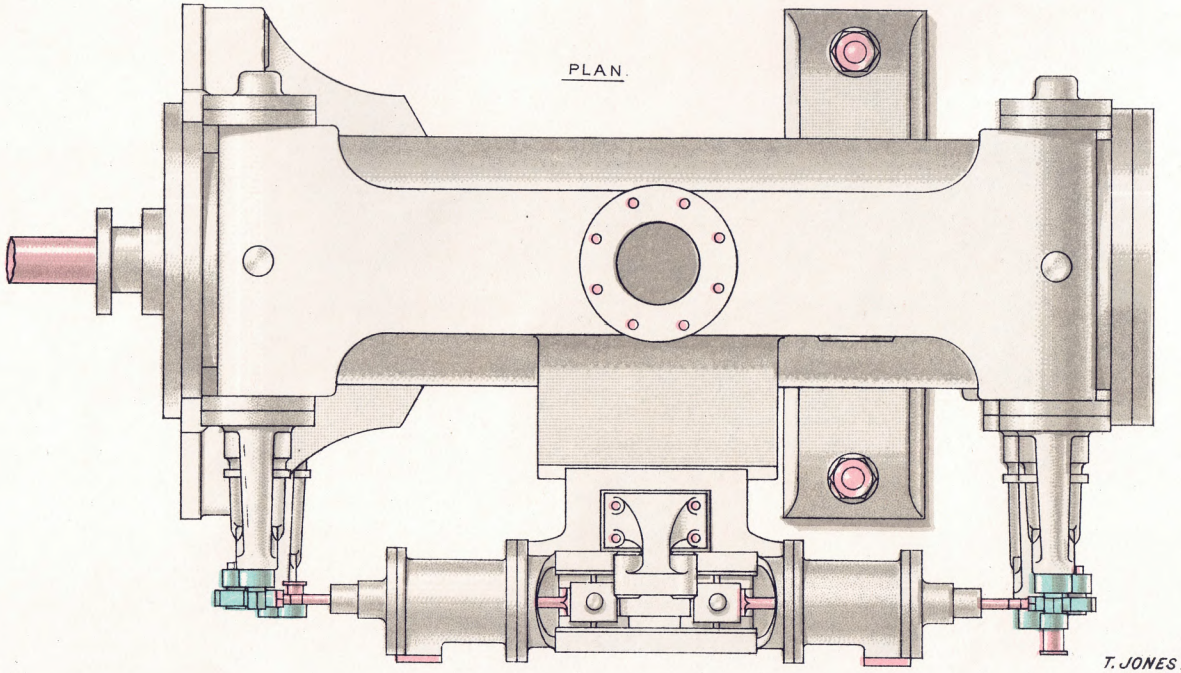
END ELEVATION



SIDE ELEVATION



PLAN.



CORLISS VALVE GEAR.

GENERAL ARRANGEMENT.

Scale 5/8" = 1 Foot

See Plates XXXVI., XXXVII., XXXVIII., and XXXIX. for Details.

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DETAILS OF CORLISS VALVE GEAR.

DETAILS OF CYLINDER.

LONGITUDINAL SECTIONAL ELEVATION

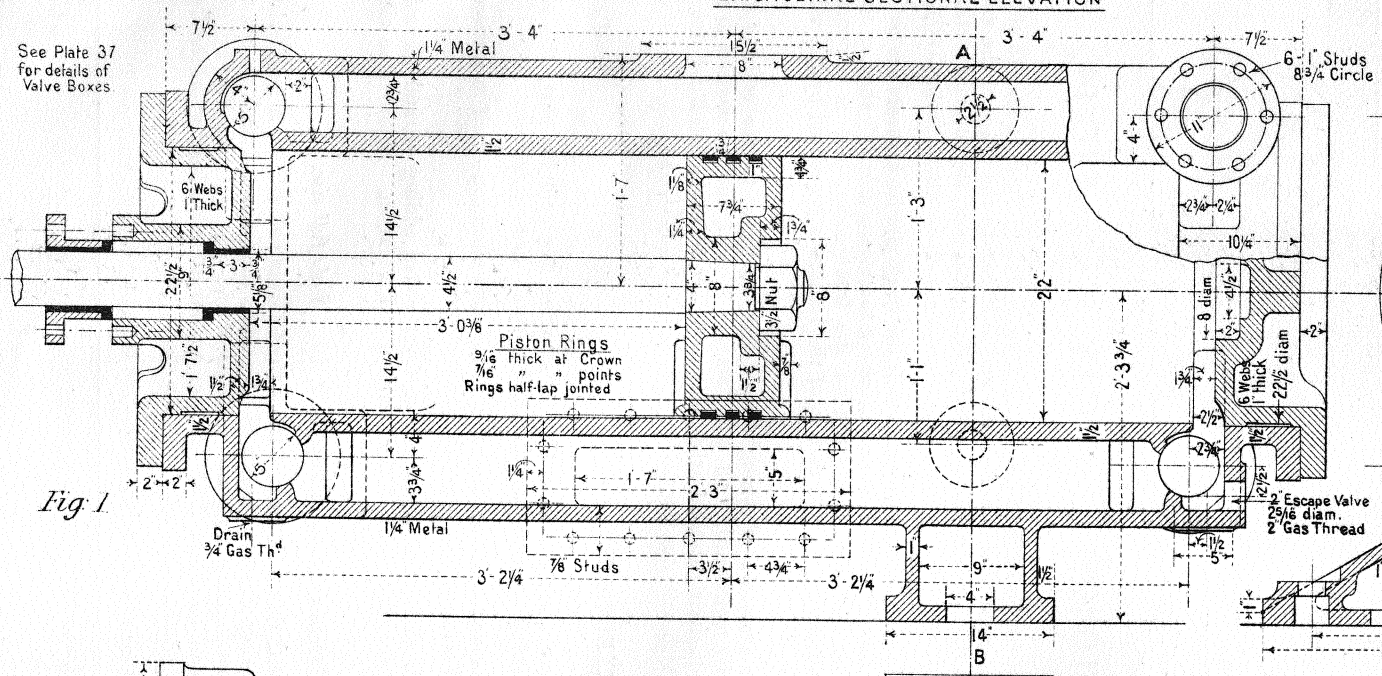


Fig. 1

SECTIONAL ELEVATION AT A. B.

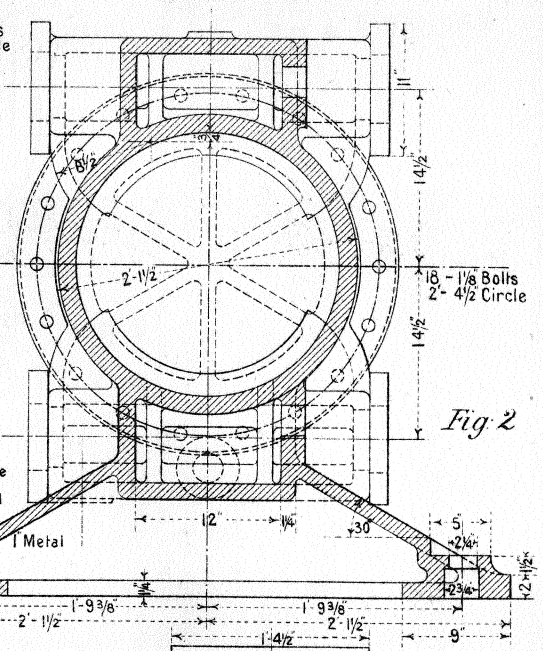
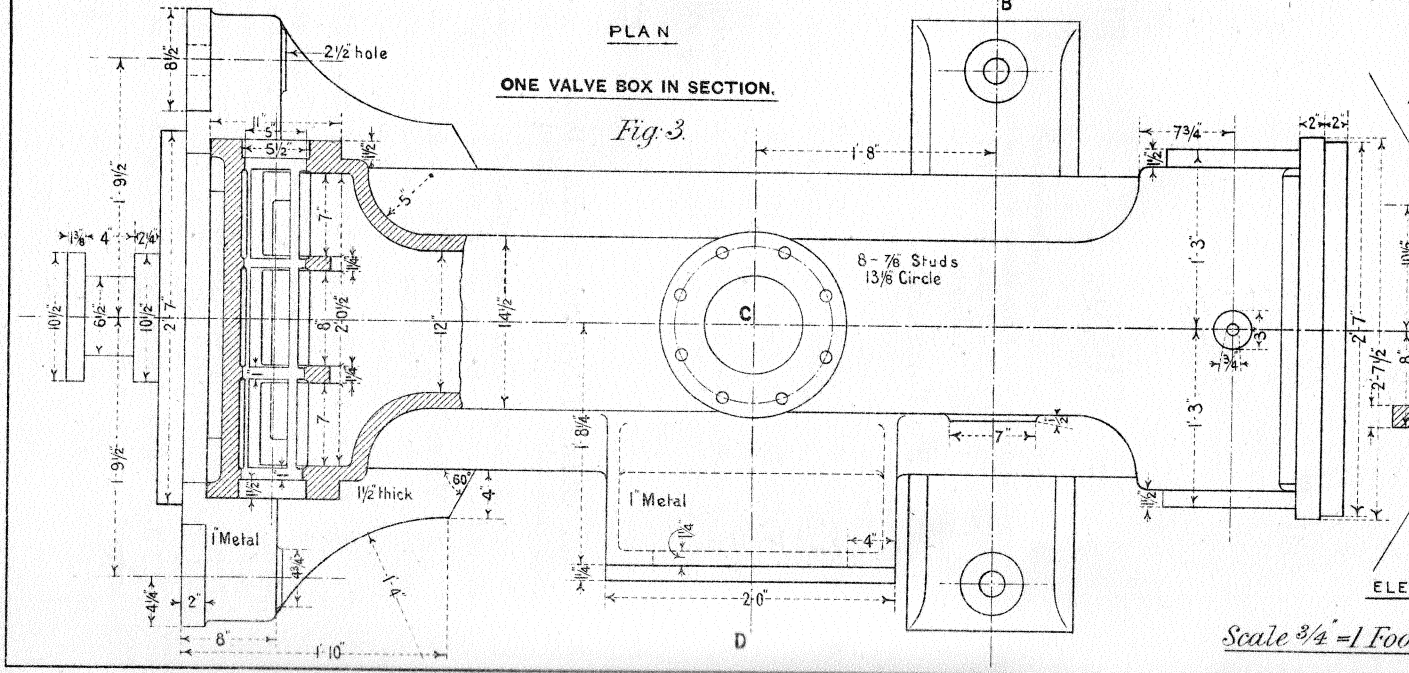


Fig. 2

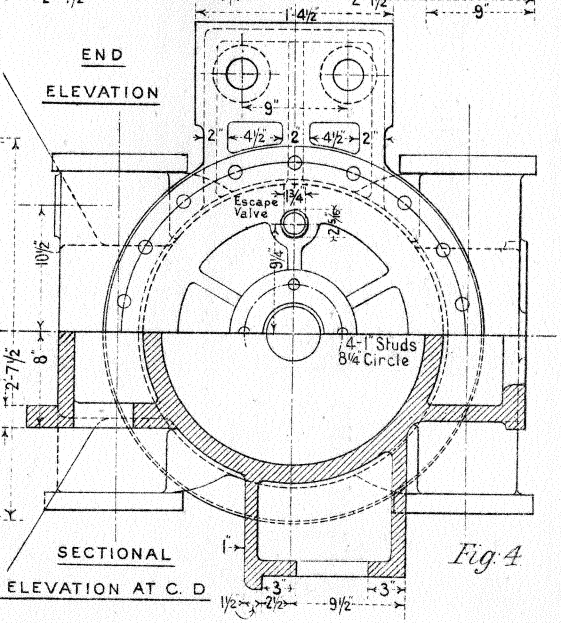
PLAN

ONE VALVE BOX IN SECTION.

Fig. 3.



END ELEVATION



SECTIONAL ELEVATION AT C. D

Fig. 4

Scale ¾" = 1 Foot.

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Plate XXXVII.—CORLISS VALVE GEAR.

STEAM AND EXHAUST VALVES, Figs. 1, 2, 3. The cross sections of the steam and exhaust valves given in Figs. 1 and 2 respectively are very similar, and the longitudinal section Fig. 3 serves for both valves. The cast-iron valves are 2′ – 3″ long, and are supported in the circular valve box of 5″ diameter at the two ends and at two intermediate places: these four bearing parts are turned to a diameter less than that of the valve by $\frac{1}{32}$″, so that the valve may turn freely without the danger of leakage. The circular parts of the valve are slotted to receive the wrought-iron spindle, and at the ends of the valve the spindle is enlarged as shown, so that no rigid connection between the valve and spindle is necessary. The back end of the spindle is carried in the bushed hole of the back cover, while the front end projects through the front cover and bracket, and carries the valve lever.

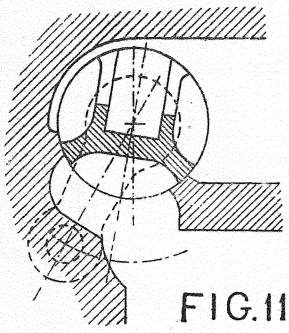


FIG. 11.

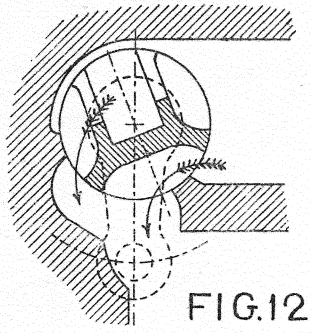


FIG. 12.

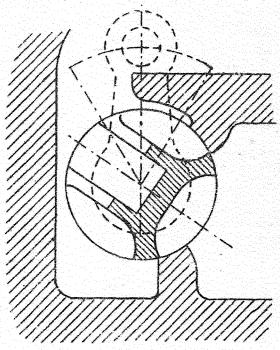


FIG. 13.

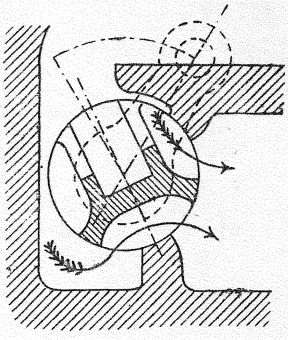


FIG. 14.

The relative positions of the levers and valves are indicated in Figs. 1 and 2, as well as in Figs. 11 and 13 of the accompanying diagrams: the steam lever is in such a position that when at the end of its stroke the edges of the valve project beyond the edges of the port by $\frac{3}{8}$″; and when the exhaust valve is just opening the port, the lever is vertical. Figs. 12 and 14 show the left-hand valves in positions during the admission and exhaustion of the steam respectively.

Valve Box Covers. Each valve box has two circular flanges against which the front and back covers are bolted by 1″ studs. The four back covers are exactly alike, but of the front covers those for the steam are $2\frac{7}{8}$″ shorter than those for the exhaust. The valve spindle passes through the stuffing box on the front cover, and is supported immediately behind the valve lever by the brass bushed bearing. End motion of the spindle is prevented by the valve lever and the wrought-iron collar pinned to the spindle.

Valve Levers, Figs. 8, 9, 10. All the lever arms are of wrought iron, and are keyed to the ends of the spindles in positions, relative to the valves, as previously mentioned. All the pins are of steel, and are secured to the levers as shown. The two steam levers are alike, but the right-hand exhaust lever differs from the left-hand one in having an additional pin for connection with the rod which actuates the valves (Fig. 5, Plate XXXIX.)

EXERCISES.

1. **Steam Valve and Spindle.** Draw the given cross section Fig. 1, showing the cylinder port, the side elevation—half in section—the end elevation to the right of the side elevation, and a plan. *Scale* $\frac{1}{2}$ *full size.*

2. **Exhaust Valve and Spindle.** Draw the given cross section Fig. 2, the side elevation—half in section—the end elevation to the right of the side elevation, and a plan. *Scale* $\frac{1}{2}$ *full size.*

3. **Valve Box Covers, Figs. 4, 5, 7.** Draw the given views of the front cover, adding an end elevation projected to the right from the plan, and a side elevation to the right of the sectional end elevation. Below these views draw the section and elevation of the back cover. *Scale* 4″ = 1 *foot.*

4. **Steam and Exhaust Levers.** Draw the levers as given in Figs. 8, 9, 10. *Scale full size.*

*5. **Valve Box, Valve, Spindle and Front and Back Covers.** Draw the following views: (*a*) A longitudinal sectional elevation through the axis of the spindle, showing the full length of the valve, the front and back covers, the section of the valve box and the lever in position, corresponding with the position of the valve given in Fig. 1; (*b*) a plan showing only the valve box in section, as in the plan on Plate XXXVI.; (*c*) an end elevation looking on the front end of the spindle; (*d*) a cross section of the valve projected to the right from the plan. *Scale* 3″ = 1 *foot.*

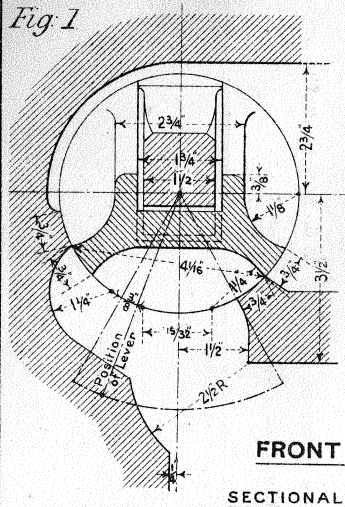
N.B.—Make these drawings either for the steam or the exhaust valve, but not for both.

* This Exercise is intended for Advanced Students.

DETAILS OF CORLISS VALVE GEAR.

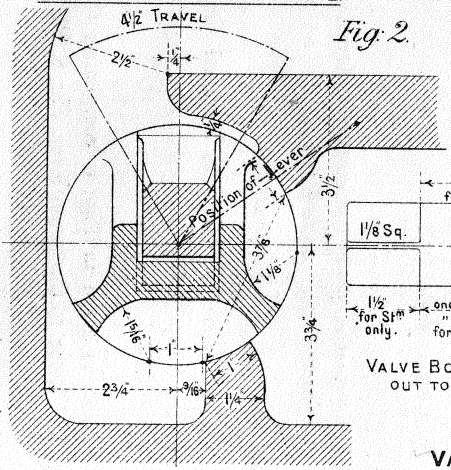
SECTION OF STEAM VALVE.

Fig. 1



SECTION OF EXHAUST VALVE.

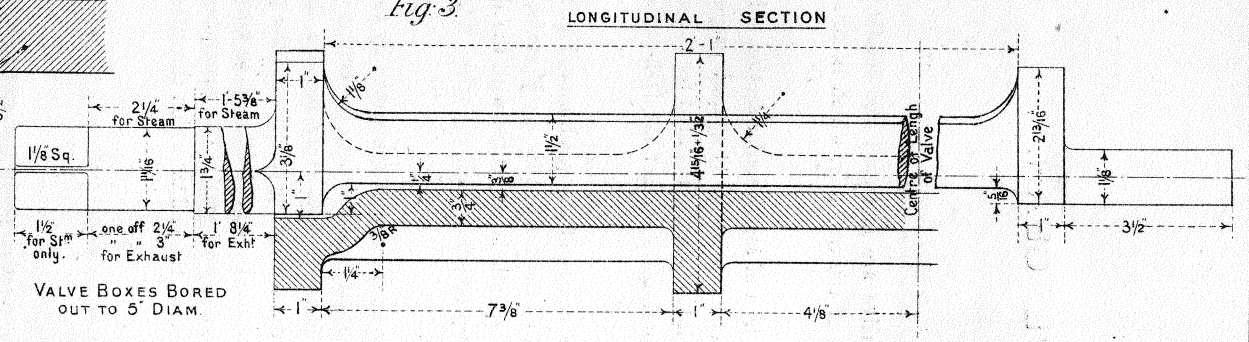
Fig. 2.



VALVES AND SPINDLES.

Scale 3"=1 Foot.

Fig. 3.

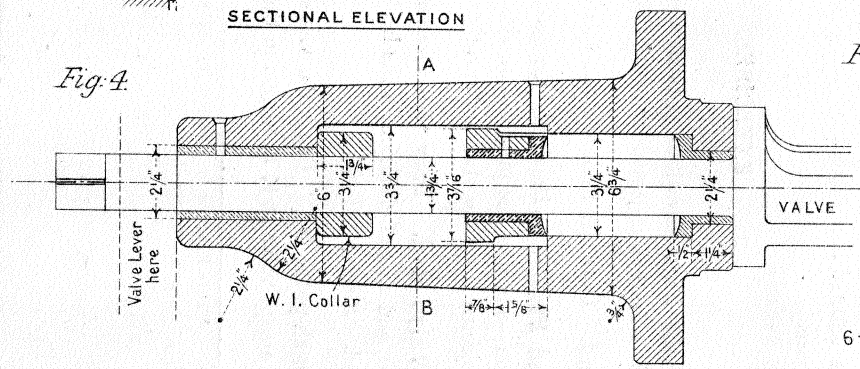


VALVE BOX COVERS.

FRONT COVER

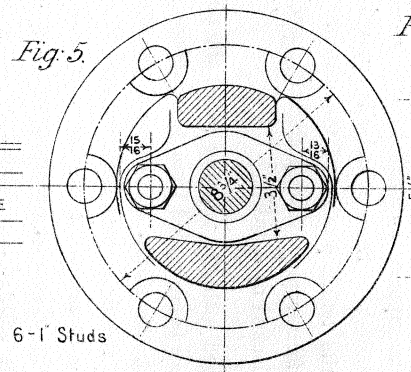
SECTIONAL ELEVATION

Fig. 4.



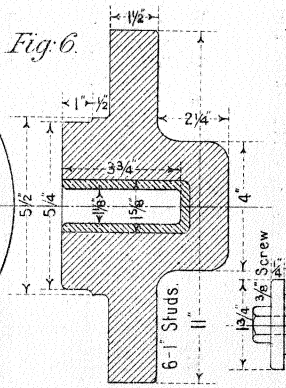
SECTION AT A. B.

Fig. 5.



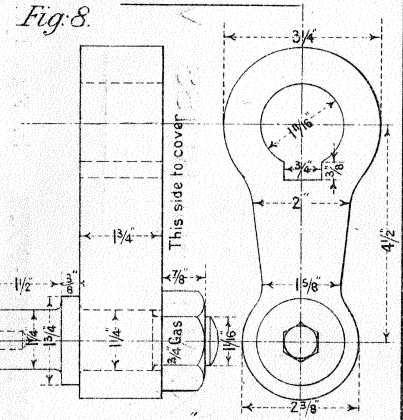
BACK COVER.

Fig. 6.



STEAM LEVER.

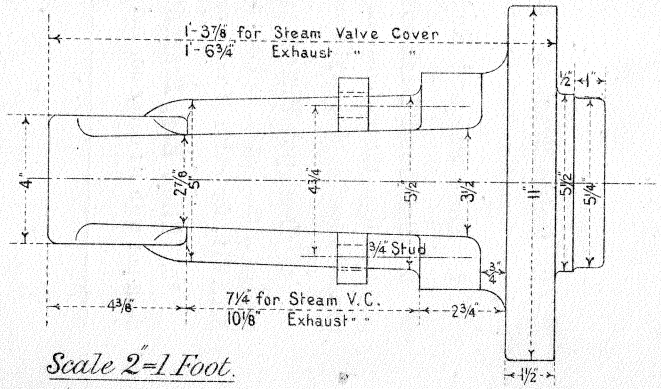
Fig. 8.



Scale 3"=1 Foot.

PLAN

Fig. 7.



Scale 2"=1 Foot.

EXHAUST LEVERS.

Fig. 9.

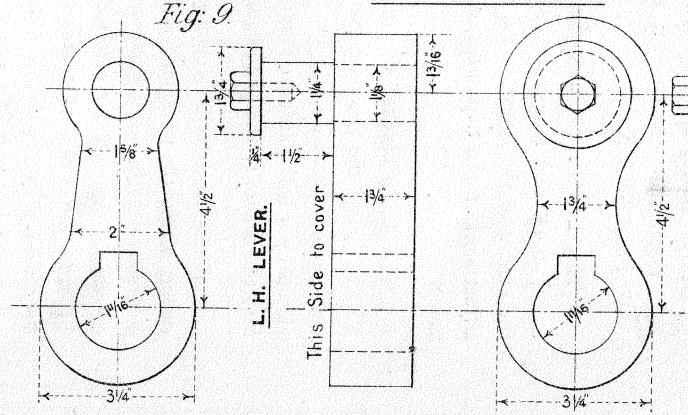


Fig. 10.

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T.G. JONES.

Plate XXXVIII.—CORLISS VALVE GEAR.

SLIDE BAR, BRACKET AND DASH-POTS. In Figs. 1 to 5 inclusive are given all the details of the mechanism concerned in the control of the steam valves with the exception of the trip gear, which is detailed on Plate XXXIX.

The slide bar, to which the two trip boxes are fixed is 19″ long, and is of cast iron of semi-circular section. It has a travel of 4½″ and moves in the guide bracket, being actuated by the rod whose end fits in the U shaped projection in the centre of its length. As seen in Fig. 2, the two grooves at right angles to its length are required for the accurate adjustment of the trip boxes, while the centre groove is the one in which the catch-plate ends of the dash-pot spindles move.

The guide bracket also serves to support the small bracket which carries the centre of the quadrants (Fig. 2, Plate XXXIX.), and the two dash-pot cylinders. Each cylinder is secured to one end of the bracket by six ¾″ studs, and its outside cover forms a support for the trunk portion of the piston. The valve spindle is connected with the dash-pot piston by a ball joint, so that the former may vibrate slightly; and the spindle proceeding from the other side screws into the centre of the piston and is locked by a nut.

When the spindle is not engaged with the tripping piece, the piston is kept at the end of the stroke by the coiled spring within the cylinder; and after being pulled from this position during the steam admission to the engine cylinder and released, the spring forces back the piston and cuts off the steam. The piston moves freely because the three grooves in the cylinder barrel allow the air to pass from between the cover and the advancing piston until the piston is 1¼″ from the cover, when this means of escape for the air is cut off, and the enclosed air, now allowed to escape only very slowly by the escape valve, Fig. 5, acts as a cushion to bring the piston quietly to rest. The promptness with which the last part of the motion is effected is regulated by the ⅝″ adjustable screw, the end of which throttles the air passing out from the compression space.

EXERCISES.

1. **Guide Bracket.** Draw the front elevation—not in section as shown—the plan, the sectional elevation projected from the plan, and the side elevation projected from the front elevation to the left. *Scale ⅜ full size.*

2. **Slide Bar and Rod End.** Draw the front and the side elevation and plan. *Scale ¾ full size.*

3. **Left-hand Dash-pot and Piston.** Draw the sectional elevation, the end elevation, the sectional plan projected from the sectional elevation—showing the piston in outside view and the escape valve as given in Fig. 5—and the cross section of the cylinder projected from the plan to the right. *Scale ¾ full size.*

4. **Dash-pot Piston and Valve Rod.** Draw the elevation and section as given in Fig. 4, completing the section of the piston, and add a plan, and an end elevation to the left of Fig. 4. Refer to the steam lever, Fig. 8, Plate XXXVII., for width of valve rod end. *Scale ¾ full size.*

*5. **Slide Bar, Bracket, Dash-pots, &c.** Draw the views given in Figs 1, 2, 3, but show the right-hand dash-pot with its cover on, and the escape valve at K in section in the plan. *Scale* 3″ = 1 *foot.*

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* This Exercise is intended for Advanced Students.

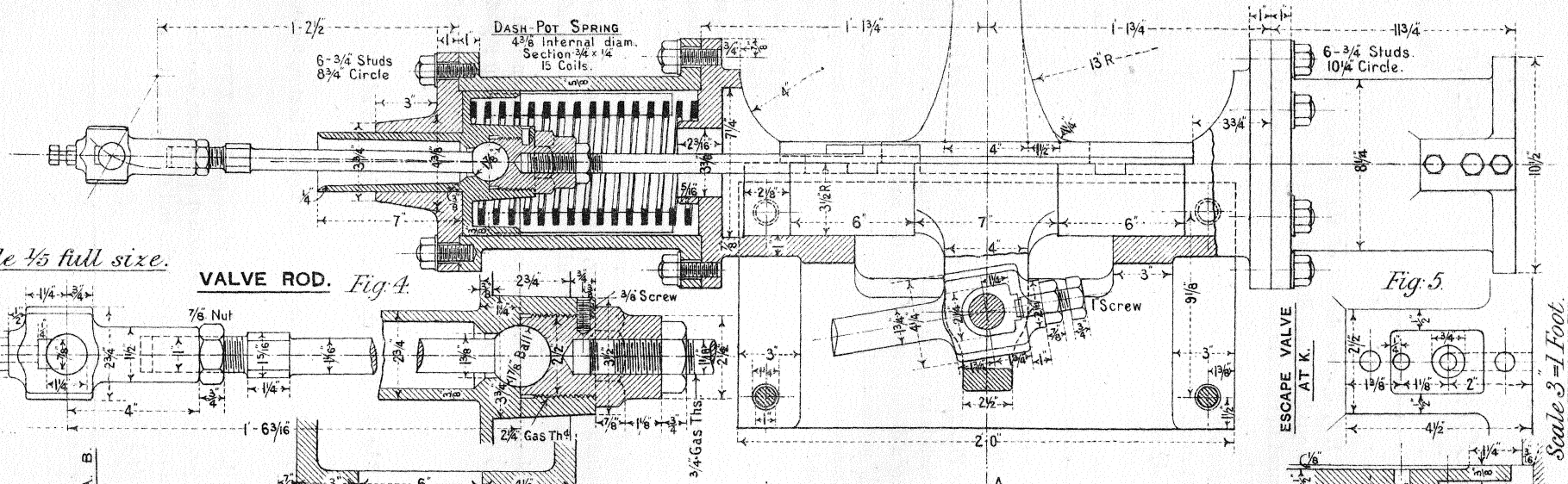
DETAILS OF CORLISS VALVE GEAR.

DETAILS OF SLIDE BAR, GUIDE BRACKET AND DASH-POTS

SIDE AND SECTIONAL ELEVATIONS.

Scale 1½" = 1 Foot.

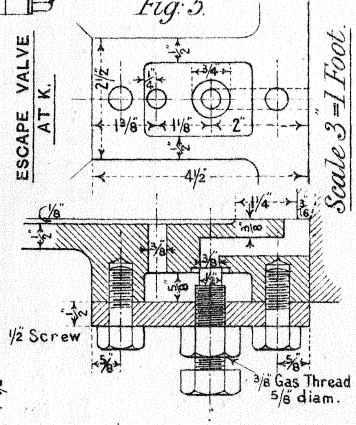
Fig. 1.



Scale ½ full size.

VALVE ROD. *Fig. 4.*

Fig. 5.



Scale 3" = 1 Foot.

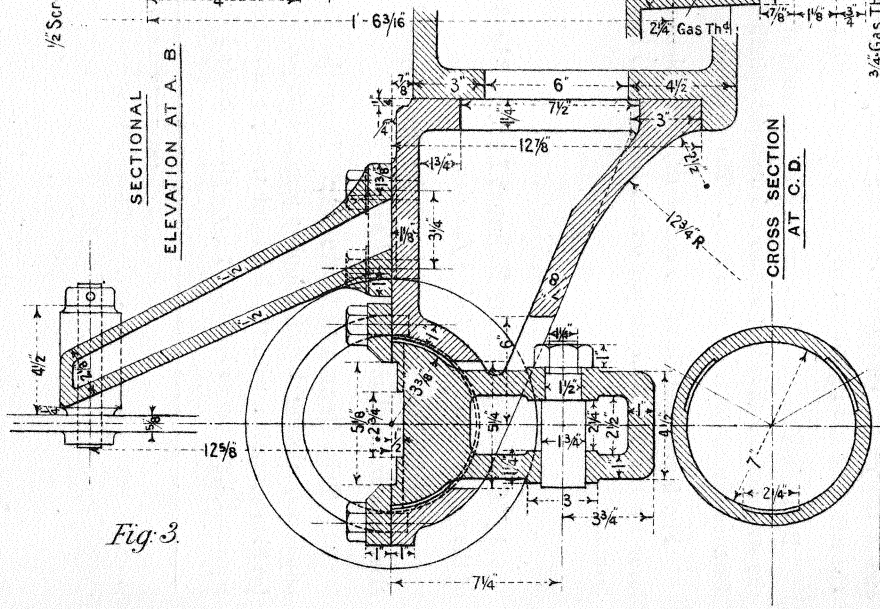
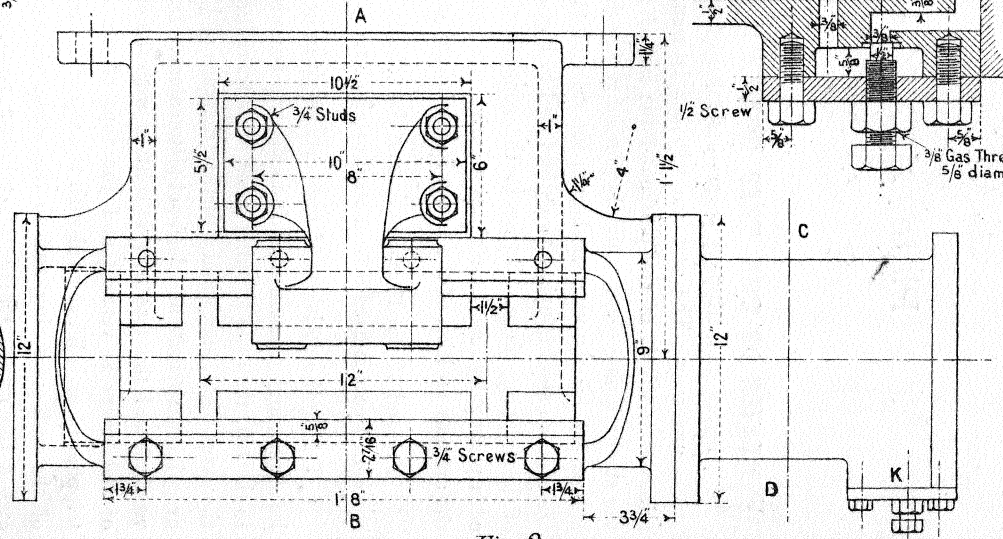


Fig. 3.



PLAN

Fig. 2.

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T.G. JONES.

Plate XXXIX.—CORLISS VALVE GEAR.

DETAILS OF THE TRIP GEAR. Figs. 1, 2, 3, give details of the left-hand trip box—with its tripping levers and tripping piece—and also of the quadrants and links required for the alteration of the cut-off by the governor. The cast-iron trip box is secured to the slide bar by four $\frac{1}{2}''$ studs, and the middle part of its base is removed to admit of the passage of the end of the dash-pot spindle through it. Passing crosswise through the box is the steel tripping piece, which is pressed gently down by the coiled spring in the box cover (see Fig. 1), and whose ends are guided by the vertical slots in the sides of the box. Fixed on the ends of the $\frac{3}{4}''$ pin, which is carried by the box, are the two steel tripping levers (detailed in Fig. 4) whose lower ends or toes are immediately below the projecting ends of the tripping piece. Owing to the connection of the tripping levers with the brass quadrants as shown, their upper ends practically remain stationary during the reciprocating motion of the trip box with the slide bar, and consequently the angular position of the levers is continually changing during the stroke.

The end of the 1″ diameter dash-pot spindle is thickened up to $1\frac{3}{8}''$, and widened to $2\frac{3}{4}''$, and on the top against the thickened part is fixed a hard steel catch-plate, $\frac{3}{8}''$ thick.

Taking the positions of the parts as given in Fig. 2, the spindle of the left-hand dash-pot is at the left-hand end of its stroke, and disconnected from the trip box which is in the middle of its stroke. Assume that the trip box is moved to the left, then the tripping piece, after travelling a distance of $2\frac{1}{8}''$ over the end of the spindle, falls down in front of the catch-plate, and, when a further distance of $\frac{1}{8}''$ is described to complete the half stroke, returns and engages with it, dragging the spindle and dash-pot piston along. During the return stroke the tripping levers become more and more nearly vertical, and the toes now in contact with the ends of the tripping piece gradually raise it; until, when the centre-line of the levers is vertical, and the tops of the toes $\frac{3}{8}''$ above the centre of the supporting pin, the bottom edge of the tripping piece is lifted level with the top of the catch plate, and the spindle being released flies back under the influence of the dash-pot spring, and so the steam valve cuts off the steam. During the remainder of this stroke, and until the end of the return stroke, this trip box remains inactive, after which the operations as above described are repeated. The left-hand and right-hand trip boxes engage with their respective dash-pot spindles every alternate stroke.

By increasing the distance between the ends of the brass quadrants, the tripping levers become vertical earlier in the stroke of the slide bar, and so the dash-pot spindle is released earlier, causing an earlier cut-off: by diminishing this distance the cut-off takes place later. The governor rod is connected with the prolongation of the left-hand quadrant.

Fig. 5 gives details of the end of the rod which actuates the exhaust levers, being connected with the right-hand lever by the $1\frac{3}{4}''$ diameter pin on the front of the lever; while the coupling rod—detailed in Fig. 6—connects the two levers.

EXERCISES.

1. **Coupling Rod for Exhaust Levers, Fig. 6.** Draw the given elevation, and add the plan showing as much of the rod as possible. *Scale $\frac{3}{4}$ full size.*

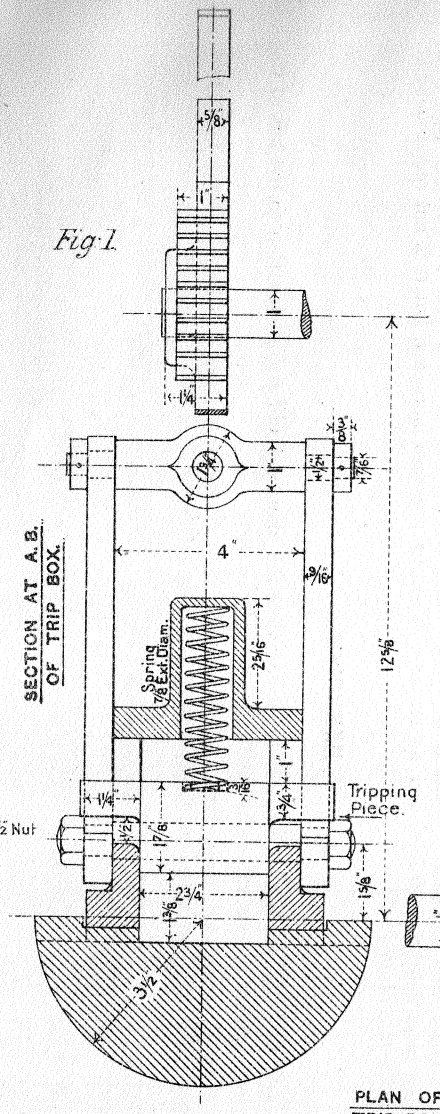
2. **Tripping Levers.** Draw the two tripping levers connected at the top and bottom by the pins, showing two elevations and a plan. *Scale full size.*

*3. **Trip Gear and Slide Bar.** Draw the complete slide bar given on Plate XXXVIII., fitted with the two trip boxes, tripping levers, tripping pieces, dash-pot spindles and the toothed quadrants, showing the following views: (*a*) Side elevation, with the left-hand trip box in section as shown; (*b*) the end elevation to the right of (*a*); (*c*) a cross sectional elevation as in Fig. 1; (*d*) a plan. *Scale $\frac{1}{2}$ full size.*

* This Exercise is intended for Advanced Students.

DETAILS OF CORLISS VALVE GEAR.

Fig. 1.

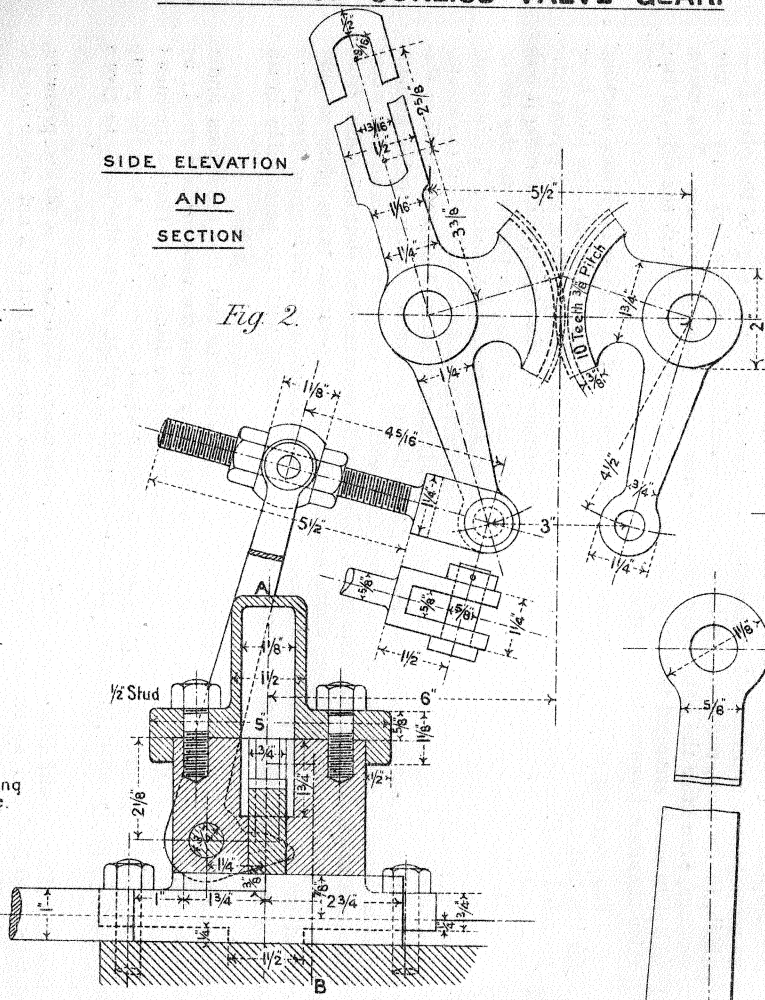


DETAILS OF TRIP GEAR.

Scale 3"=1 Foot.

SIDE ELEVATION AND SECTION

Fig. 2.



PLAN OF TRIP BOX

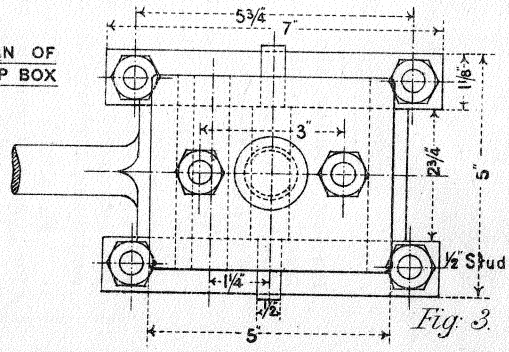
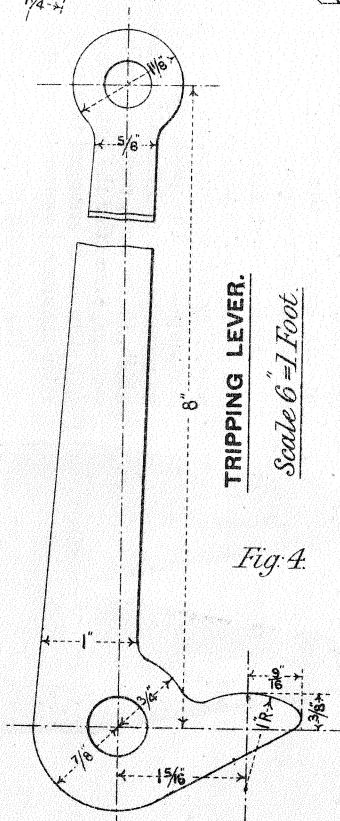


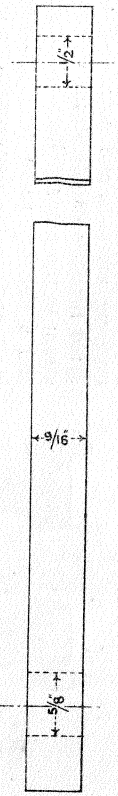
Fig. 3.



TRIPPING LEVER.

Scale 6"=1 Foot.

Fig. 4.



Scale 3"=1 Foot.

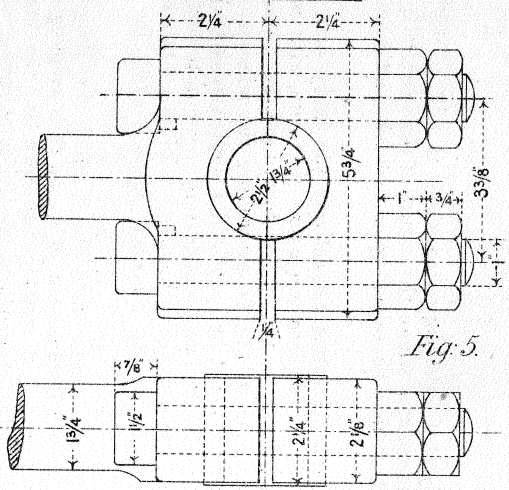


Fig. 5.

COUPLING ROD FOR EXHAUST LEVERS.

Scale 3"=1 Foot.

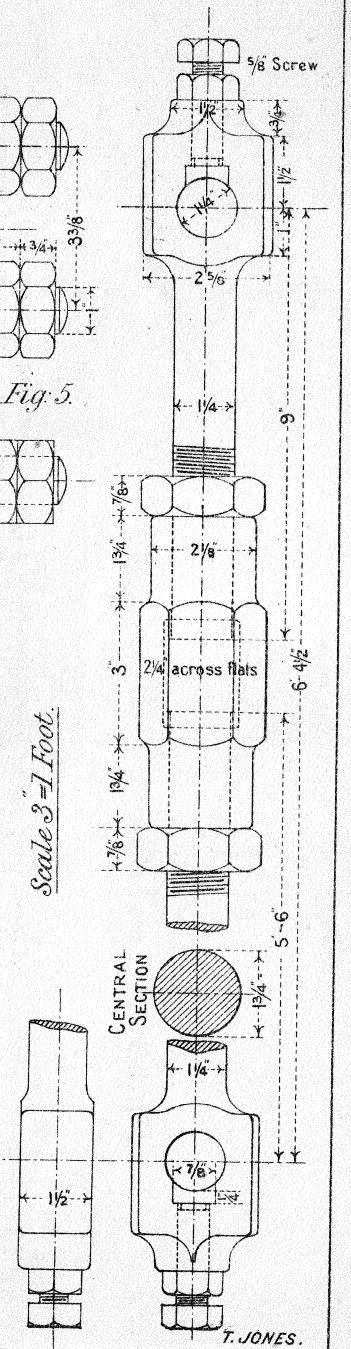


Fig. 6.

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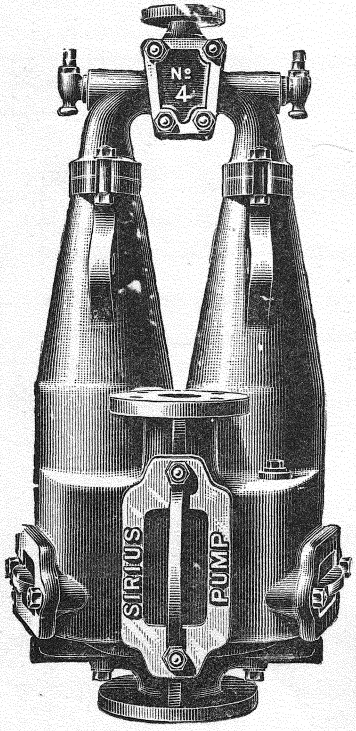
Plate XL.—THE "SIRIUS" PULSATING PUMP.

FIGS. 1 to 6, inclusive, and the accompanying illustration show a type of pulsating pump which is well suited for the purpose of raising water readily and quickly in emergency cases, and where the nature of the work calls for an apparatus that requires no care or skilled attendance, but which may be relied upon to work continuously without any risk of failure or breakdown.



The pump is made up of two castings, called respectively the **body** and the **steam head** H or neck. The body is divided into two equal chambers, with ends tapering upwards, and connected together at the top by the steam head, in which is fitted Brooke's Patent Steam Valve—detailed in Fig. 6—controlling the admission of steam to the pump. Each of the chambers has at its lower end a suction valve (S.V.), and a delivery valve (D.V.), the two suction valves opening from a common suction inlet, and the two delivery valves into a common delivery outlet. Covers are provided on the body of the pump which can be readily removed, when desired, for an examination of the valves.

An important feature of this pump is the steam valve, Fig. 6, which is so designed and constructed as to give a rapid cut-off to the admission of steam, thus avoiding any possibility of wire-drawing, and resulting in a striking economy in the steam consumption. The quick action of the valve also ensures regularity of stroke, while its construction, and the fact of its being free to swing on the top edge of the plate G—which, in its turn, rocks on its bottom edge—enables it to always bed truly on the seatings, even after the latter may have become worn through long use. The valve and plate are so arranged that they cannot get out of place, or touch the sides of the valve chamber, however the pump is placed.

The working of the pump may be briefly described as follows:—When starting for the first time, the pump is "primed" by pouring water in through the plug hole provided for that purpose. Steam is then turned on at the stop valve, and passes into one or other of the chambers, pressing on the surface of the water, and forcing it out through the delivery valve in the discharge chamber, whence it passes to the rising main. The surface of the water in the chamber being smooth when steam is admitted, there is practically no condensation until the discharge is completed, when the steam, having reached the level of the discharge pipe, is met by a small jet of water from the injection tube, and is rapidly condensed; this causes a partial vacuum to be formed, which instantly closes the steam valve, and refills the chamber by drawing in water through the suction valve. The steam valve, by its movement to shut off steam from the first chamber, allows steam to enter the second chamber, where exactly the same operation takes place as just described in the first chamber; and in this way the pump continues to work automatically, discharging from each chamber alternately. When properly regulated, the pump will give a uniform discharge with no perceptible break between the beats.

The adjustment is effected by opening or closing the air valves, Fig. 4, more or less, to suit the conditions under which the pump is working. These valves open inwards, and admit air to the pump when the vacuum is formed: by their regulation they allow the chambers to fill at the right speed for giving a continuous discharge. Their adjustment is best effected by screwing them down until both are only slightly open and to an equal amount, then, when the pump has been started, they should be adjusted equally until the exact amount of opening, which allows the pump to give a continuous discharge, is obtained.

For a total lift of 20 feet, this size of pump will discharge 10,000 gallons per hour. With steam at 60 lbs. pressure, the pump will force to a total height of 90 feet, and so on as the steam pressure increases, but it is not recommended on economical grounds to exceed 90 feet.

EXERCISES.

1. **Steam Head, H.** Draw the two given sections, complete the plan, and add a side elevation to the left of the sectional front elevation. Show the air valves in position. *Scale $\frac{2}{3}$ full size.*

*2. **Pulsating Pump, complete.** Draw Figs. 1, 2, 3, and add a front elevation to the left of Fig. 1. *Scale* 3″ = 1 *foot.* Draw the air valve, injection tube and steam valve separately to a *scale $\frac{3}{4}$ full size.*

* This Exercise is intended for Advanced Students.

SECTION AT A B.

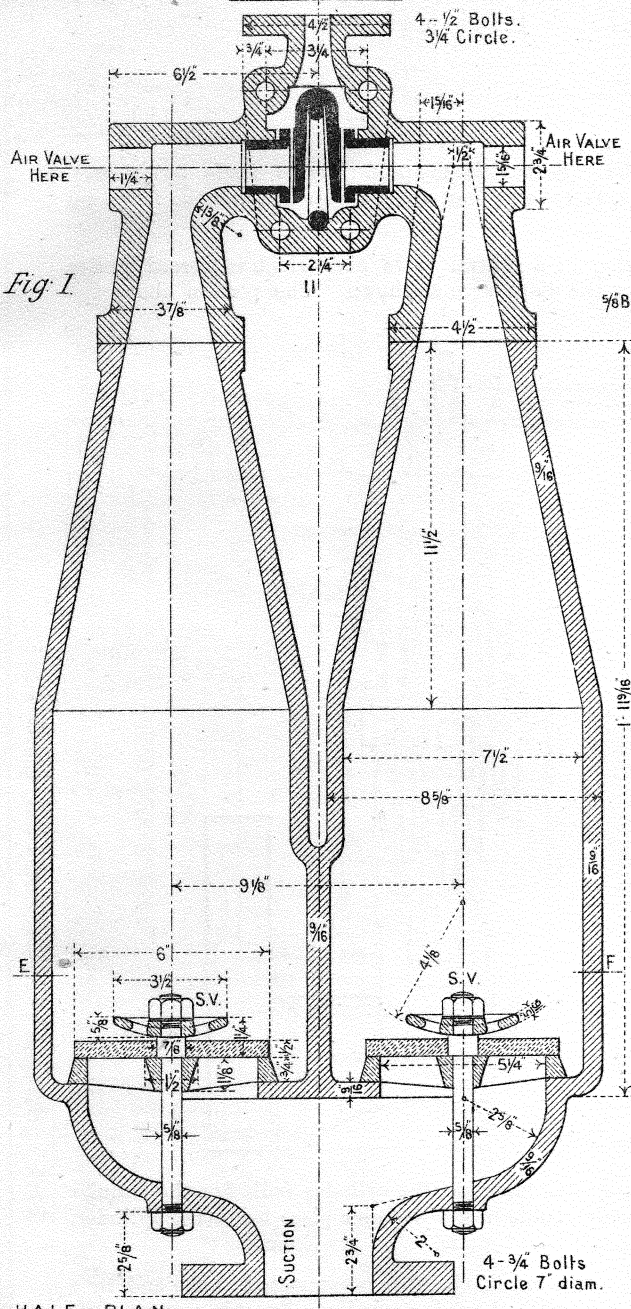


Fig. 1.

SECTION AT C. D.

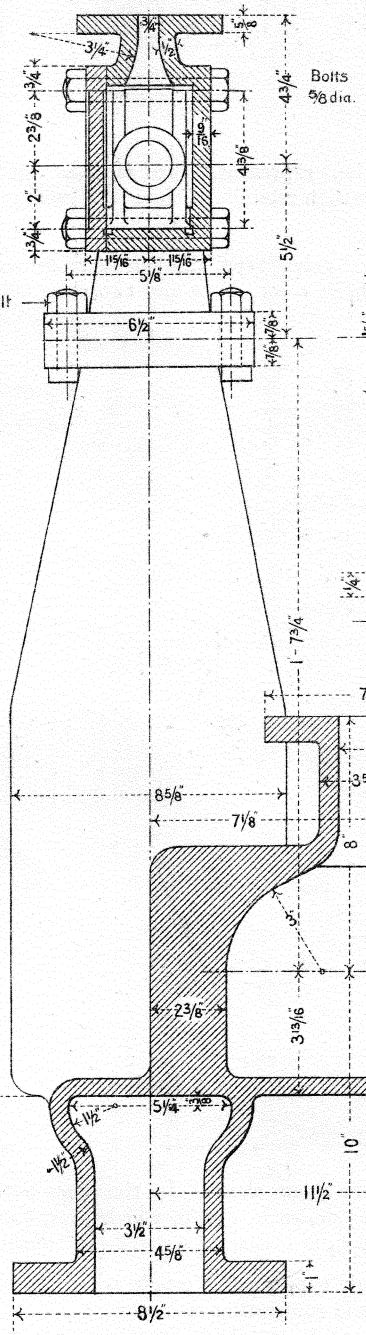


Fig. 2.

AIR VALVE.

Scale ½ full size.

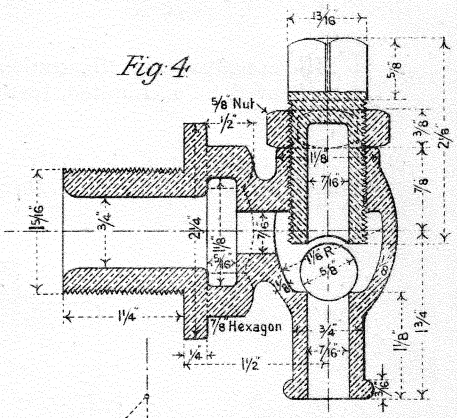


Fig. 4.

INJECTION TUBE.

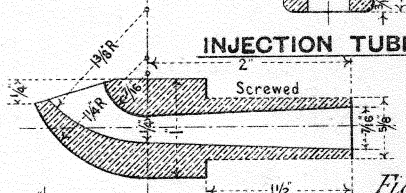


Fig. 5.

STEAM VALVE.

Scale 4"=1 Foot.

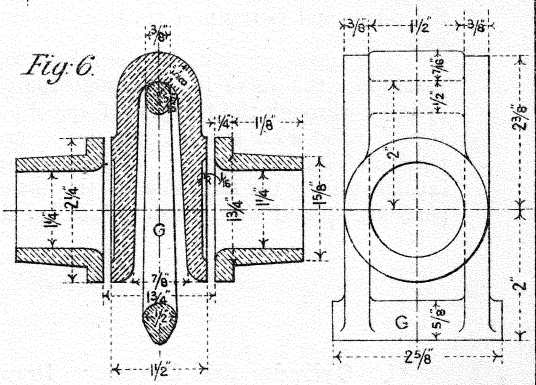


Fig. 6.

SECTION AT E. F

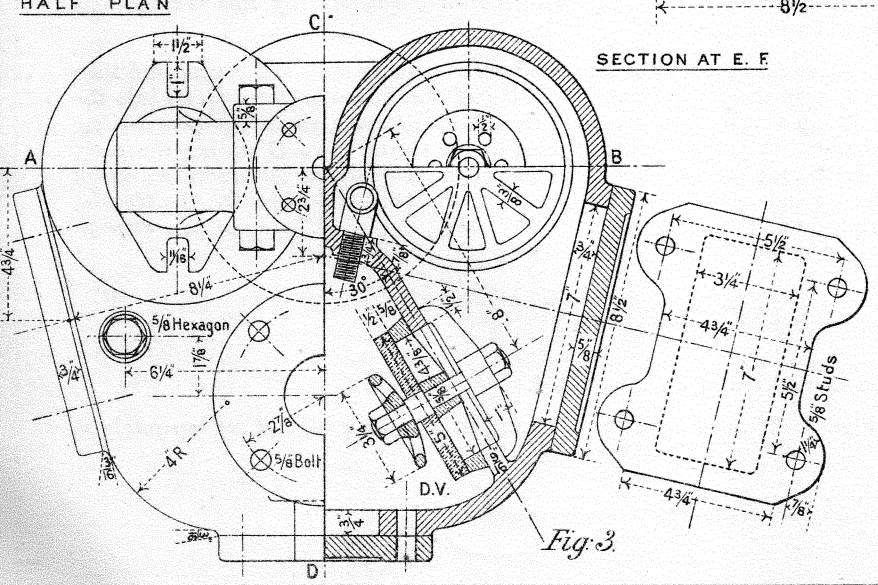


Fig. 3.

'SIRIUS' PULSATING PUMP.

Scale 2"=1 Foot.

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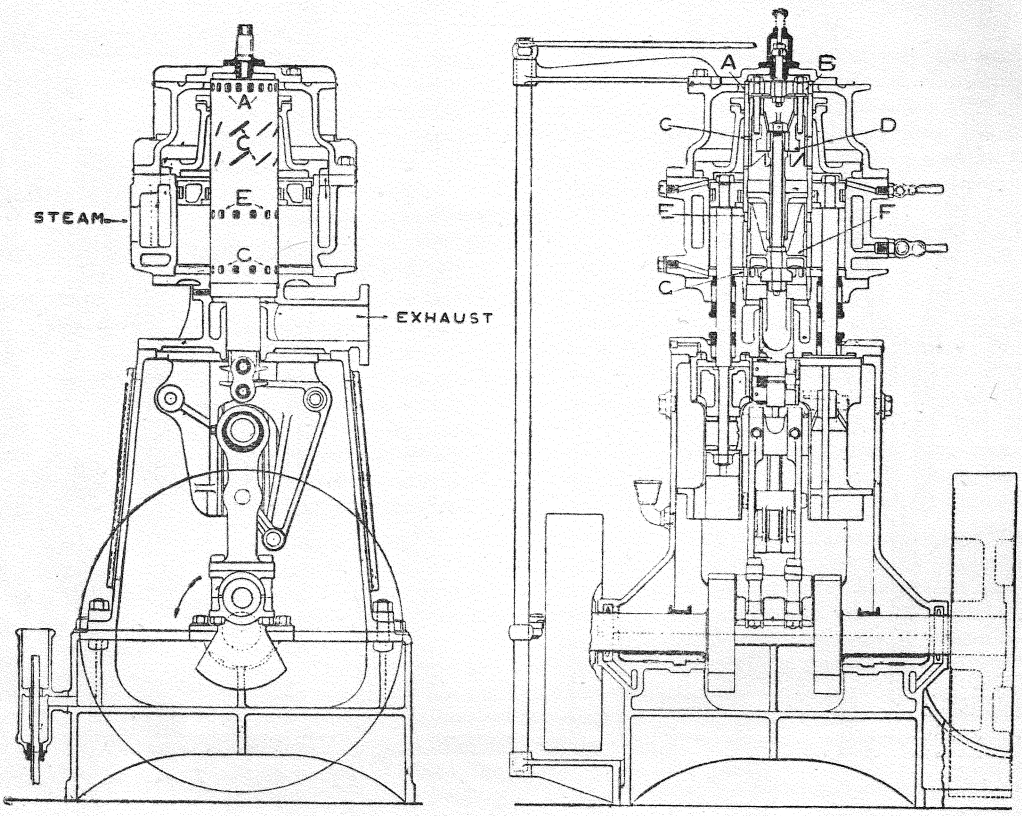
Plate XLI.—HIGH-SPEED ENGINE.

THE accompanying illustration represents two sections of the "Scott" High-speed Engine, made by Messrs. Reavell & Co., Limited, Ipswich: details of the cylinder, covers, valves and liner are given on this and the following plate.

The engine is of the central-valve type, the valves reciprocating in a central valve liner which is pierced by five rows of ports, A, C, C, E, G, three rows above and two rows below the diaphragm as shown. The portion above the



diaphragm forms the high-pressure steam chest. In the space between this liner and the cylinder walls fits the annular piston, having two piston rods as shown in Fig. 5, which pass, through glands in the distance piece below the cylinder, into the crank chamber, where each is bolted to a crosshead running in a bored guide.

The valve gear is of the link type: a bell crank lever pivoted in the crank chamber is connected at one end by a link pinned near the centre of the connecting rod, and by a second link with the valve spindle. By this arrangement the valves and piston perform their up and down strokes together.

The steam, entering by the inlet branch, passes up between the inner and outer cylinder walls and covers, and then passes into the valve liner through the ports A near the top. From the inside of the liner the steam passes into the cylinder through the two sets of spiral ports C up to the point of cut-off, the clearance space above the piston being already filled with steam at the initial pressure, and the cut-off being effected by the steam valve D during the early portion of its down-stroke. After an early cut-off, the precise point of which is controlled by the governor, the steam expands during the remainder of the down-stroke; and while the crank is turning the bottom dead-centre, the transfer ports are opened by the valve F, called the transfer and exhaust valve. [*Continued on next page.*

EXERCISES.

*1. **Cylinder and Covers.** Draw the views given in Figs. 1, 2, 3, 4. *Scale* 3″ = 1 *foot.*

*2. **Piston.** Draw the views given in Figs. 5, 6, 7, and show the rings in position in Fig 6, and not separately as in Fig. 8. *Scale* ½ *full size.*

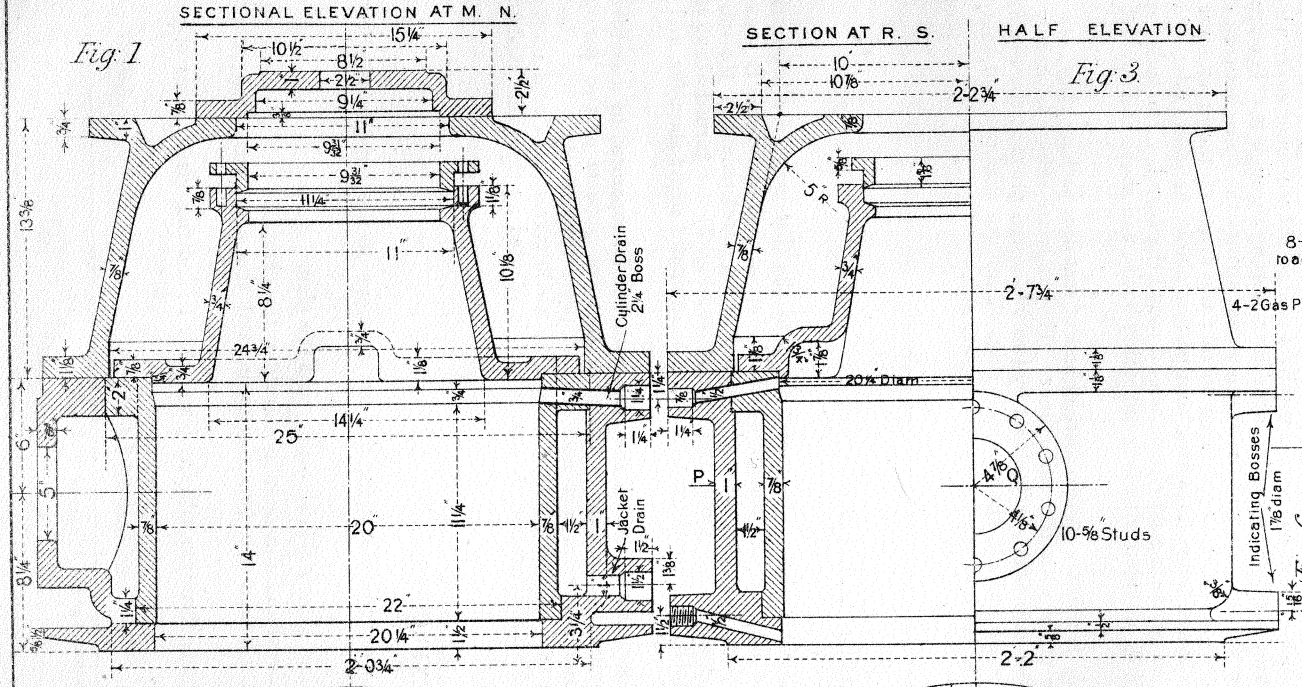
* These Exercises are intended for Advanced Students.

THE 'SCOTT' HIGH SPEED ENGINE.

DETAILS OF CYLINDER AND COVERS.

SECTIONAL ELEVATION AT M. N.

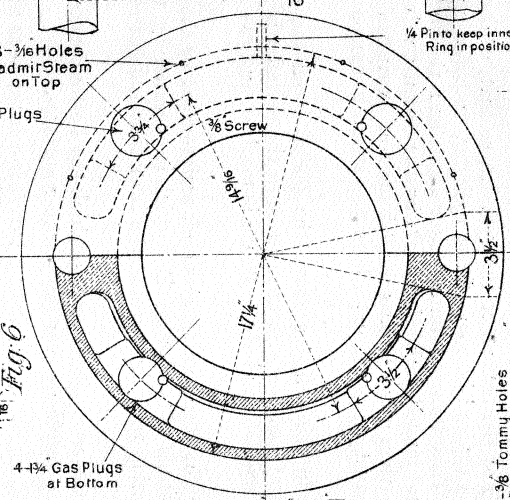
Fig. 1



SECTION AT R. S. HALF ELEVATION

Fig. 3

Fig. 6



DETAILS OF PISTON.

Fig. 5.

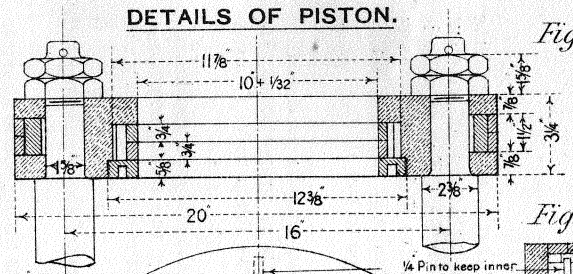
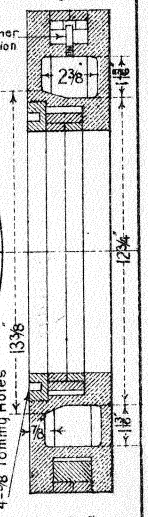
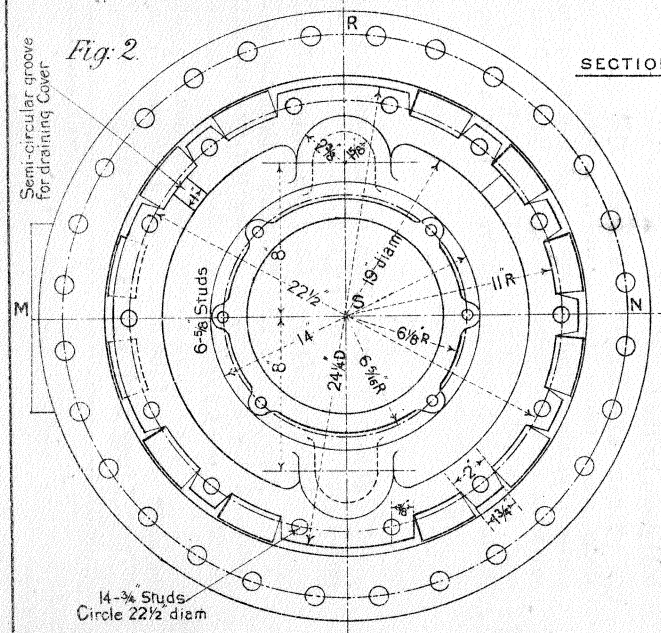


Fig. 7



Scale 1½" = 1 Foot

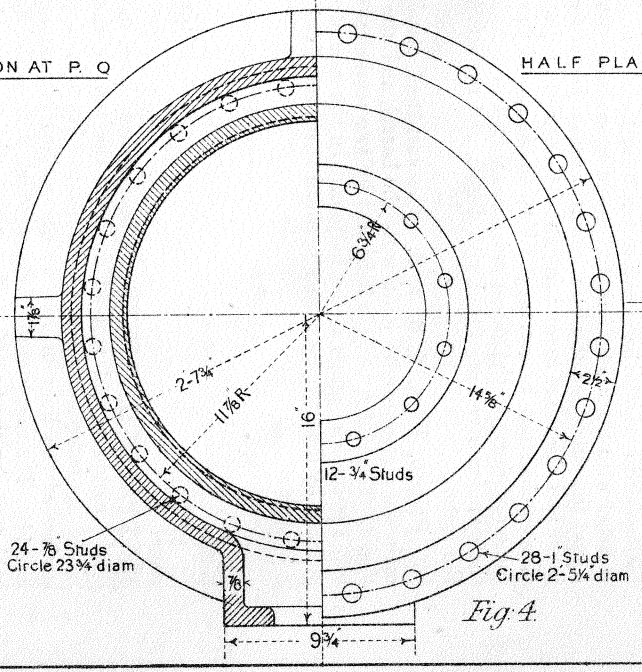
Fig. 2



PLAN WITH OUTER COVER REMOVED.

SECTION AT P. Q HALF PLAN

Fig. 4



PISTON RINGS.

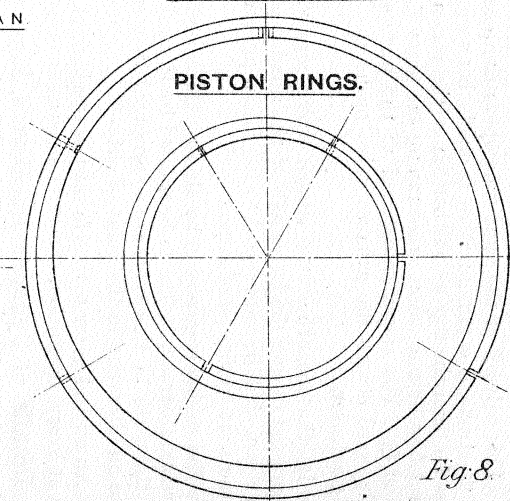
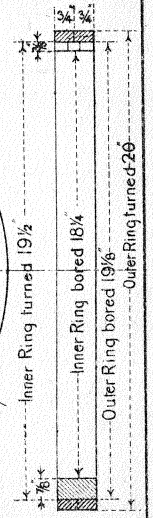
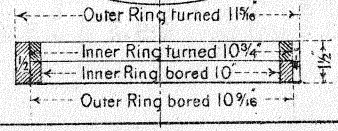


Fig. 8.





T. JONES.
T.G. JONES.

PLATE XLI.—*Continued.*

This valve F at the same time opens the ports G at the bottom of the cylinder, so that, while the piston is making its up-stroke, a communication is made between the top and bottom of the cylinder, transferring steam at constant pressure from the top to the bottom of the piston. This transfer continues for about half the stroke. The transfer is closed first by the piston over-running the ports E, and immediately afterwards by the exhaust valve F closing the ports E and G. The steam transferred to the underside then completes its second stage of expansion, and near the end of the upward stroke the exhaust valve opens the exhaust ports G, and allows this steam to escape to the atmosphere or the condenser.

In the meantime the steam which remained in the cylinder above the piston when the transfer is closed, is compressed during the latter half of the upward stroke; and the clearance space in the cylinder is so proportioned that this steam shall be compressed to the initial pressure when the end of the stroke is reached, and the steam valve D opens for the next admission of steam.

The engine is governed by altering the cut-off. The steam valve, although reciprocated by the slide rod and having a constant stroke, is free to be rotated by the guide studs in the bridge B—which is operated by the shaft governor—and the ports in this valve are so arranged in connection with the ports in the liner that a slight rotary movement will cause an alteration in the point of cut-off.

An oil and water bath is formed in the bottom of the crank chamber into which the bottom end of the connecting rod dips at every revolution, throwing a constant stream of lubricant over the working surfaces.

Details of Cylinder and Covers, Figs. 1, 2, 3, 4. The working barrel is a loose liner fitting inside an outer casing—into which the steam passes from the steam pipe—and closed on the top by a conical shaped inner cover which is fitted with a stuffing box and gland to make a steam-tight joint with the valve liner passing through it. The space round the outside of the barrel forms a steam jacket for the cylinder, and the steam passes up into the space between the inner and the outer cover through the notches in the top flange of the working barrel: the flange of the inner cover is also notched out to correspond with the shape of the barrel flange, excepting that portion above the steam inlet where some resistance to the steam must be exerted in order to ensure a good circulation all round the barrel. The jacket and the cylinder barrel are fitted with drains, and the latter is provided with four indicating boxes, two above and two below the piston.

Piston, Figs. 5, 6, 7, 8. The cast-steel piston is fitted with two distinct sets of cast-iron packing rings, one to maintain a steam-tight joint with the barrel, and the other with the valve liner. The rings are shown separately in Fig. 8. The piston body is lightened by two semi-circular core holes, each closed by two 2″ screwed plugs at the top, and two $1\frac{3}{4}$″ screwed plugs at the bottom. In the case of each packing, the two split rings of uniform thickness are kept in position by a small peg fitting between them and fixed in the spring ring by riveting its end.

Plate XLII.

DETAILS OF LINER. The cast-iron liner, in which the valves move, fits into the distance piece below the cylinder, and is held down at the top by the liner cover through which the spindle of the bridge B passes. As before mentioned, the liner has five sets of ports which are best represented in the development of the inner surface of the liner in Fig. 2: the surface is assumed to be cut along the link K (see Fig. 3) and turned about the line H. The cast-iron diaphragm, which divides the liner into two distinct parts, rests against a slight shoulder, and is held down by the two $\frac{3}{4}$″ steel struts as shown.

Steam and Exhaust Valves. The two valves are attached to the same spindle, and separated by a cast-iron sleeve, which moves through the diaphragm. The cylindrical surface of the exhaust valve consists of two parallel portions, which control the passage of the steam through the transfer and exhaust ports respectively. The steam valve has one set of seven spiral ports in its cylindrical surface, and a lower zig-zag edge which corresponds with another set. The slight rotary motion of the valve, necessary for an alteration in the cut-off, is effected by the guide studs on the bridge, which pass through the two internal boxes.

EXERCISES.

1. **Steam Valve.** Draw the sectional and the outside elevation, the development of the outside cylindrical surface, and the plan. *Scale $\frac{3}{8}$ full size.*

2. **Exhaust Valve.** Draw the sectional elevation, the outside elevation, and the plan. *Scale $\frac{1}{2}$ full size.*

*3. **Two Valves and Spindle.** Draw the sectional and the outside elevation, the plan, and half the developed surface of the steam valve. Place the development between the two elevations, and the plan below the outside elevation. *Scale $\frac{3}{8}$ full size.*

*4. **Liner.** Draw the sectional elevation, the outside elevation with the plan below it, and the development of half the inner surface of the liner. *Scale $\frac{3}{8}$ full size.*

*5. **Liner and Valves.** Draw the given views, Figs. 1 to 5. *Scale $\frac{3}{8}$ full size.*

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* These Exercises are intended for Advanced Students.

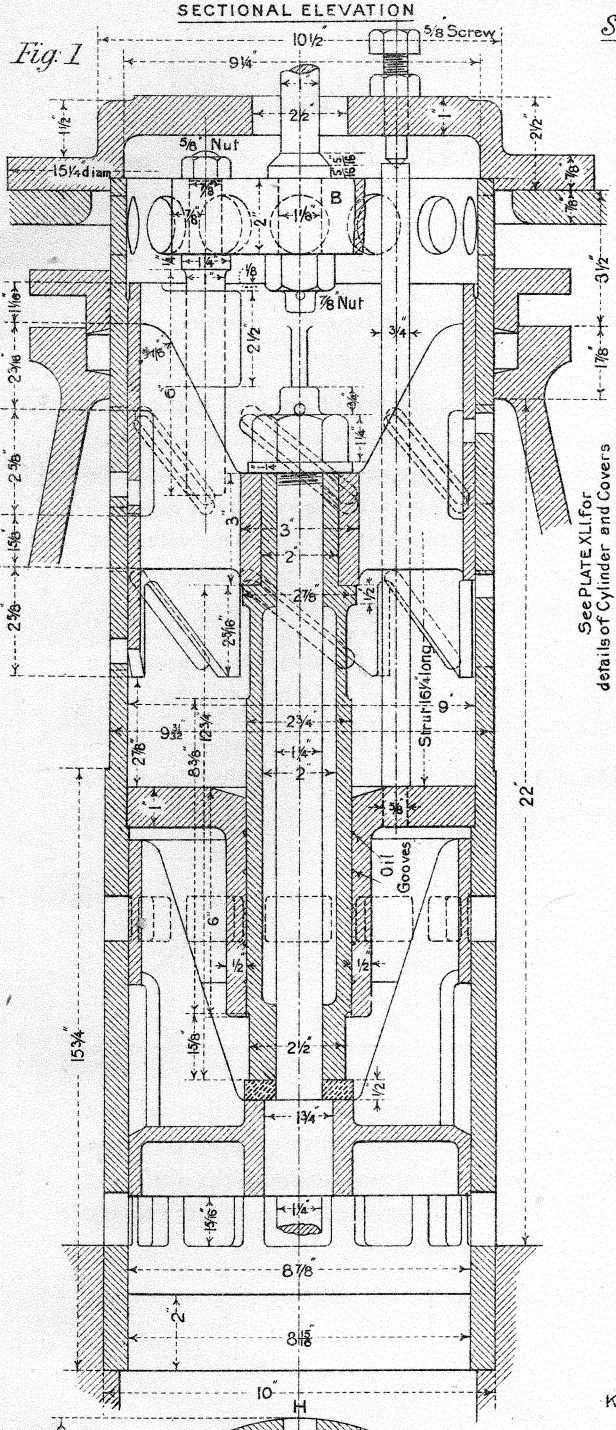
THE 'SCOTT' HIGH SPEED ENGINE.

DETAILS OF LINER AND VALVES.

Scale ⅓ full size.

SECTIONAL ELEVATION

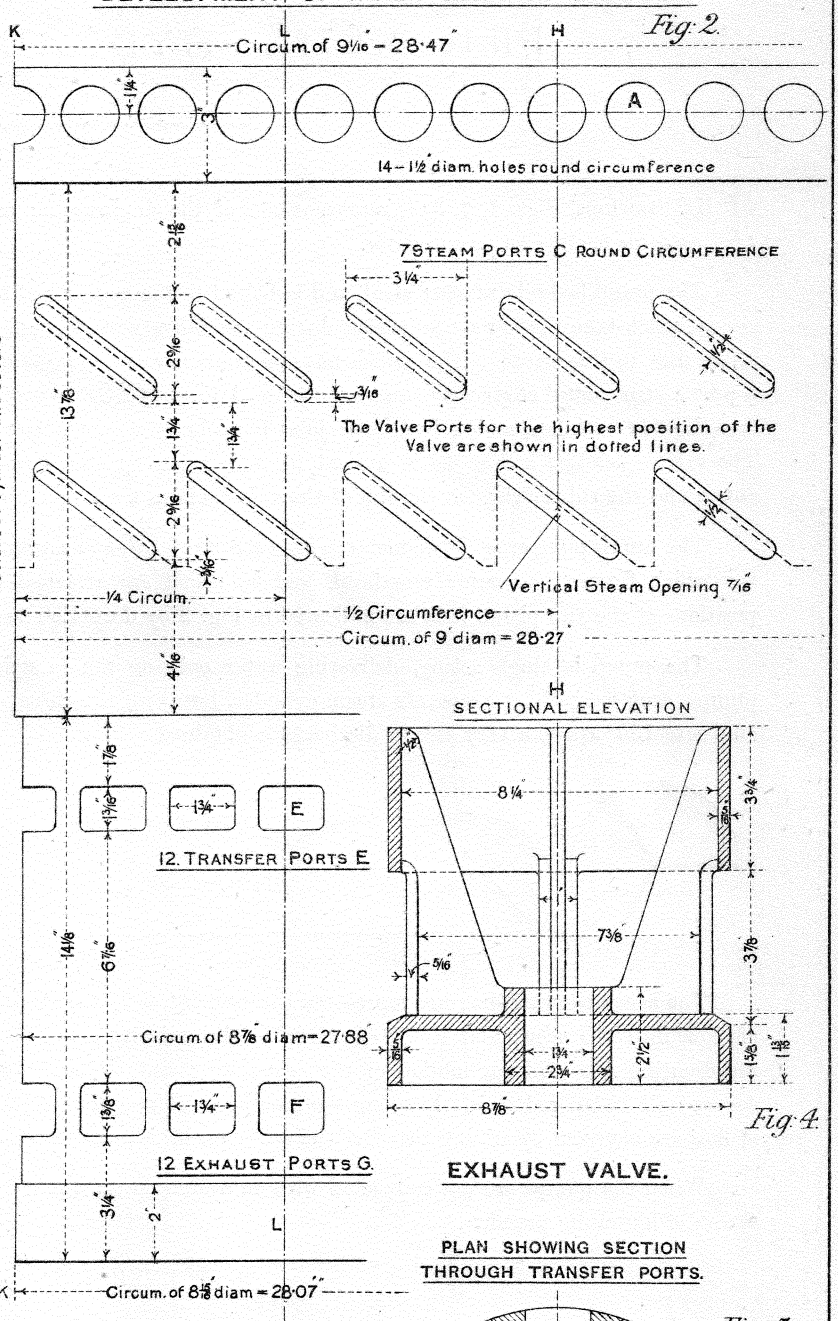
Fig. 1



See PLATE XLI for details of Cylinder and Covers

DEVELOPMENT OF INNER SURFACE OF LINER.

Fig. 2



SECTIONAL ELEVATION

Fig. 4

EXHAUST VALVE.

PLAN SHOWING SECTION THROUGH TRANSFER PORTS.

Fig. 5

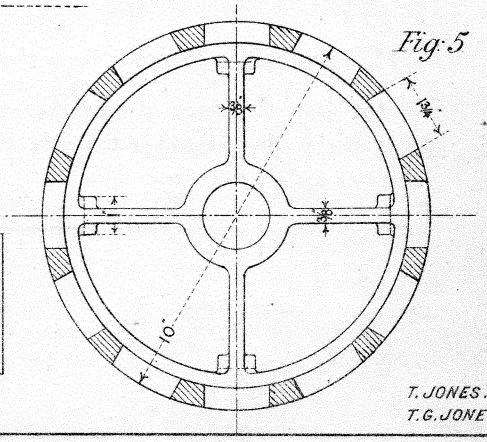
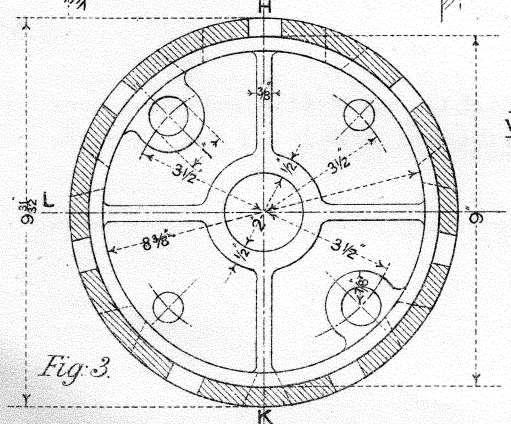


Fig. 3



PLAN OF STEAM VALVE WITH SECTION THROUGH STEAM PORTS.

TRAVEL OF VALVE	2 1/16"
VERTICAL STEAM OPENING	7/16"
CORRESPONDING CUT OFF ¼ STROKE	
TRANSFER OPENING	1⅛"
EXHAUST OPENING	15/16"
TRANSFER CLOSES ON UP-STROKE	5½"

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T.G. JONES.

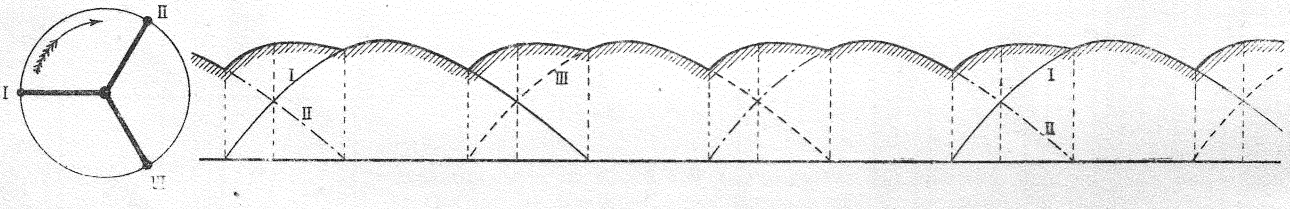
Plate XLIII.—HYDRAULIC PUMP.

THE drawings, Figs. 1, 2, 3, 4, represent one of the single-acting pumps of a three-cylinder crank pumping engine, used for feeding an accumulator.

The pump body is of cast steel, and is bolted to the engine bed by four 1″ bolts; the feet at the back butt against snugs which take the horizontal thrust during the delivery stroke, and so relieve the holding-down bolts from a shearing stress due to this cause. The pump has one suction valve and one delivery valve, and each valve box is closed on the top by a strong steel cover with square flange held down by four 1″ studs: the cover projects into the cylindrical hole for a considerable distance, and a hydraulic joint is made by a narrow leather ring in the recess at the top of the valve box. The valve - detailed in Fig. 4—is guided in its motion by the four wings and the 1″ diameter pin passing into the cover, and the rubber ring on the top of the valve acts as a cushion when the valve is lifted against the cover.

The pump plunger is $3\frac{1}{8}$″ diameter, with a stroke of 18″, and a total length of 3′ – 1″; the T end is secured to a cross-bar which forms the engine crosshead, and to which are attached the two piston rods of the steam cylinder. The positions of the two piston rods are indicated in Fig. 2 by dotted circles, $1\frac{3}{4}$″ diameter and $10\frac{5}{8}$″ apart.

The pump is single-acting, delivering water only on the *in* stroke of the plunger; but, by combining three such pumps, each worked by a separate steam cylinder, but with the three cranks on the same shaft placed symmetrically at angles of 120° apart, a very steady discharge is obtained.



The accompanying diagram represents the velocity of flow from each of the three pumps, and the resulting velocity of flow into the accumulator. Each curve is the velocity curve of the plunger during the delivery stroke on a base representing the uniform motion of the crank pin; and, since the cranks are placed symmetrically on the shaft, the curves will be spaced regularly along the base line. The ordinates of the curve which represents the resulting velocity of flow are obtained by adding together the ordinates of the curves which overlap one another.

When the pumps are not connected with an accumulator, a relief valve is placed on the delivery pipe to prevent excess of hydraulic pressure.

EXERCISE.

*1. **Hydraulic Pump.** Draw the views given in Figs. 1, 2, 3. *Scale* 4″ = 1 *foot.*

Or, draw the three given views, and add a side elevation to the right of the end elevation, and also a cross sectional elevation—through the axis of the delivery valve—projected from the plan. *Scale* 2″ = 1 *foot.* Detail the valve to a *scale* $\frac{3}{4}$ *full size.*

* This Exercise is intended for Advanced Students.

HYDRAULIC ACCUMULATOR PUMP.
3⅛" DIAMETER, 18" STROKE.

SECTIONAL ELEVATION

Scale 2"=1 Foot.

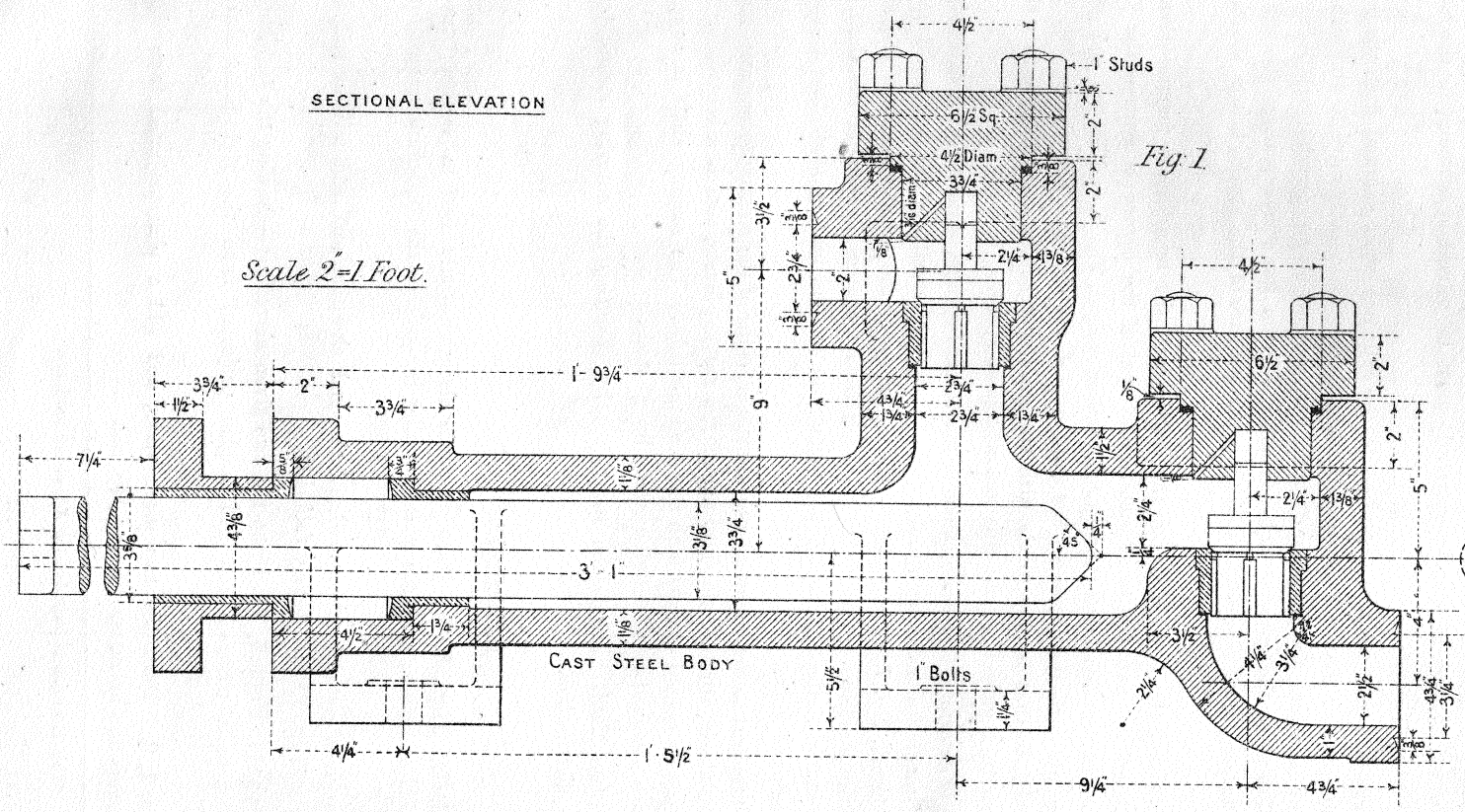


Fig. 1.

END ELEVATION.

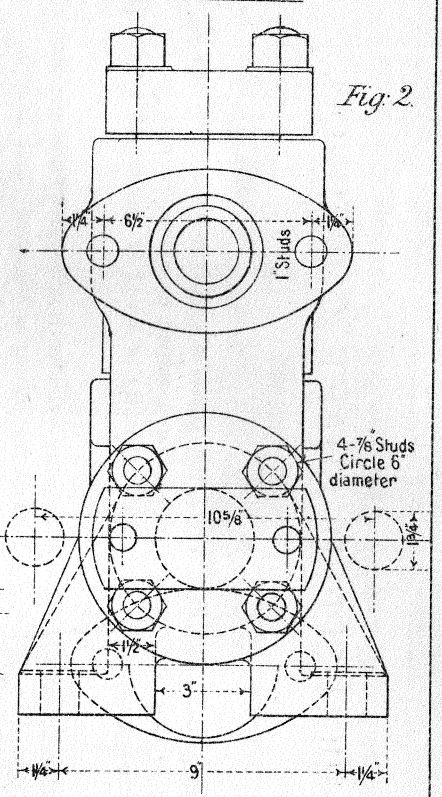


Fig. 2.

PLAN.

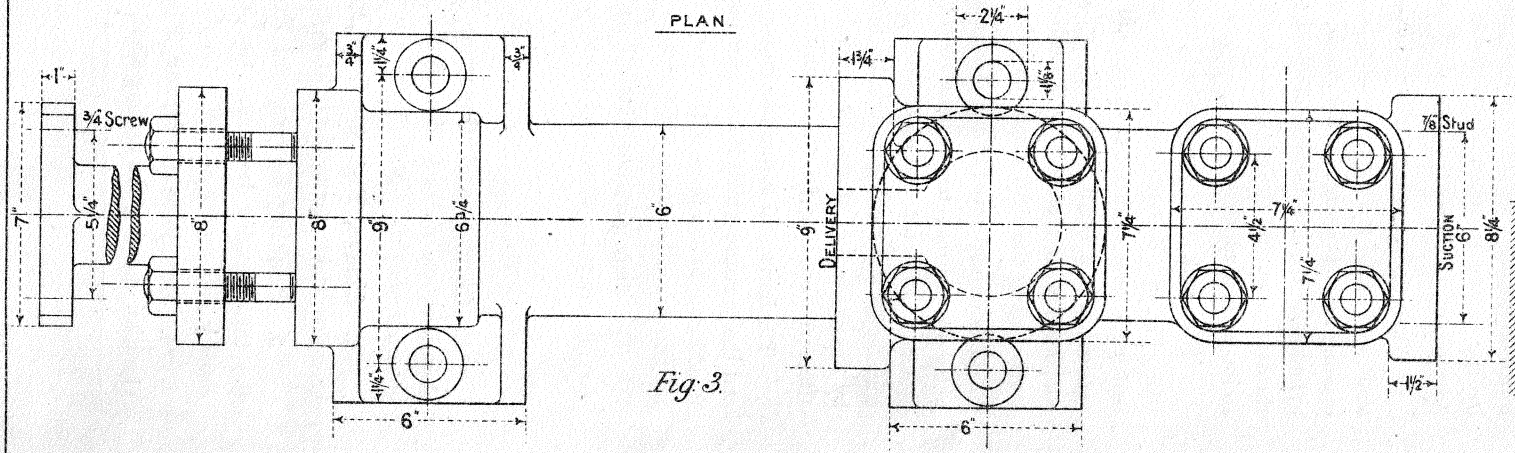


Fig. 3.

PUMP VALVE.

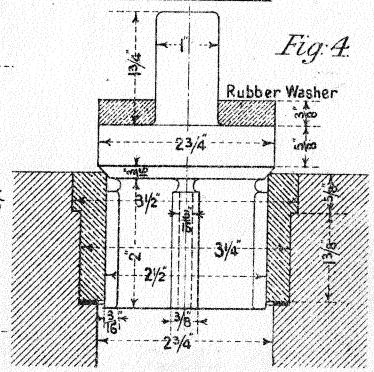


Fig. 4.

Scale 4"=1 Foot.

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Plate XLIV.—HIGH-SPEED SHAFT GOVERNOR.

FIGS. 1, 2, represent the general arrangement, and Figs. 3 to 7, the details of a shaft governor used on a high-speed compound engine suitable for driving a dynamo direct. The governor is connected with an equilibrium throttle valve (not shown in the drawing) so that the uniformity of speed is maintained by altering the pressure of steam to the cylinders.

The steam distribution to the high-pressure and the low-pressure cylinder is effected by a single central valve which gives fixed points of cut-off in the two cylinders; and hence the greater or less work which must be developed by the engine to prevent a decrease or an increase of speed respectively must be caused by a change in the initial pressure of the steam to the high-pressure cylinder.

When the speed increases it is evident that more work is developed in the cylinders than is taken from the crank shaft, and hence the governor must be so arranged that this increase of speed causes the throttle valve to diminish the opening for the passage of the steam, and so reduce the pressure of steam and consequently the work developed in the cylinders. When a decrease of speed takes place the governor acts so that the steam has a free passage through the throttle valve, and the additional work developed, on account of the increased pressure of the steam, brings the speed to its normal value.

The crank shaft projects outwards beyond the bearing, and on the end is fixed the brass carrier for the governor balls, Fig. 3. Between the conical ends of the two screws at each forked end of the carrier is centred the brass bell-crank lever, which has at the end of the horizontal arm the governor ball or weight, Fig. 5, and at the end of the vertical arm a small steel roller which fits into the recess at the oval end of the sleeve. The sleeve, Fig. 4, is connected with the shaft by a feather key, so that it may rotate with the shaft, and, at the same time, have a slight motion along the shaft when the governor balls move in or out due to a change of speed.

The normal speed of the governor is determined by the tensions of the vertical springs connecting the two weights, but the speed may be regulated within small limits during running by adjusting the tension of the horizontal spring, attached to the top end of the rocking levers, Fig. 7. The two steel blocks fitting in the circular recess of the sleeve transfer to the rocking levers the horizontal motion of the sleeve resulting from a change of speed of the shaft, and, by the connection of the throttle valve rod with the end of the horizontal arm on the rocking shaft, this movement alters the opening for the steam through the valve.

The horizontal spring has its ends attached to the engine casing and the cross-bar of the rocking levers respectively, and the pressure which it exerts on the sleeve, through the medium of the rocking levers, acts as a controlling force in addition to the force of the two springs connected directly with the governor balls. The rocking shaft is supported by two brass brackets, Fig 6, which are attached to the engine casing by $\frac{5}{8}$″ studs.

The shaft governor detailed on Plate XXX. controls the speed, not by *throttling* the entering steam, but by varying the valve travel and the steam distribution.

EXERCISES.

1. **Carrier and Governor Balls, Figs. 3, 5.** Draw the side elevation—only half in section; two end elevations, one on each side of the side elevation; and the plan, showing in position the bell-crank levers for the governor weights. *Scale $\frac{3}{4}$ full size.*

2. **Sleeve, Fig. 4.** Draw the given sectional elevation and the end elevation, and add a plan and a side elevation, the latter to the right of the end elevation. *Scale $\frac{3}{4}$ full size.*

3. **Rocking Levers and Brackets, Figs. 6, 7.** Draw the two given elevations—showing the full length of the throttle valve lever and the brackets in position—and add a plan projected from the right-hand elevation. *Scale $\frac{1}{2}$ full size.*

*4. **Complete Governor, Figs. 1, 2.** Draw the two given views, and add a plan projected from the side elevation omitting the rocking shaft, levers and brackets. *Scale $\frac{3}{8}$ full size.*

*This Exercise is intended for Advanced Students.

HIGH SPEED SHAFT GOVERNOR.

SIDE ELEVATION

END ELEVATION

Scale 2"=1 Foot.

Fig: 1.

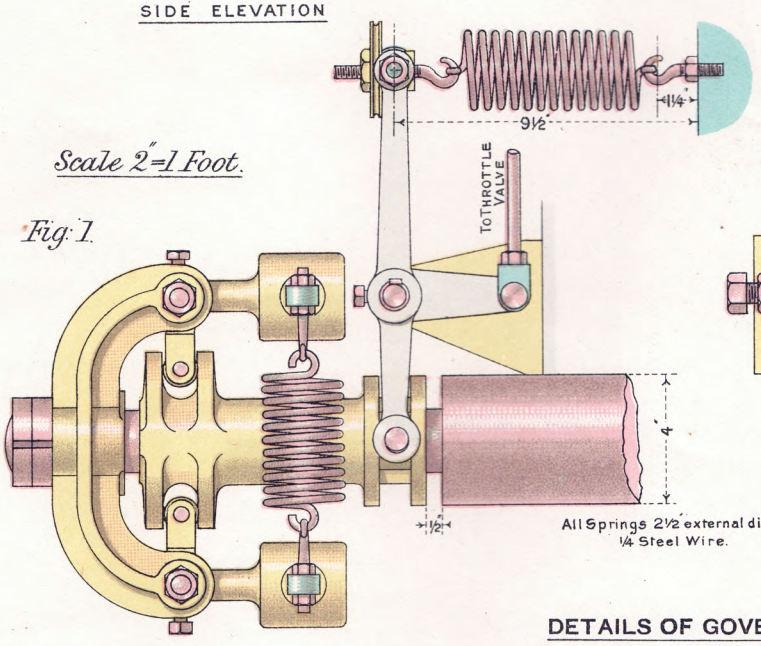
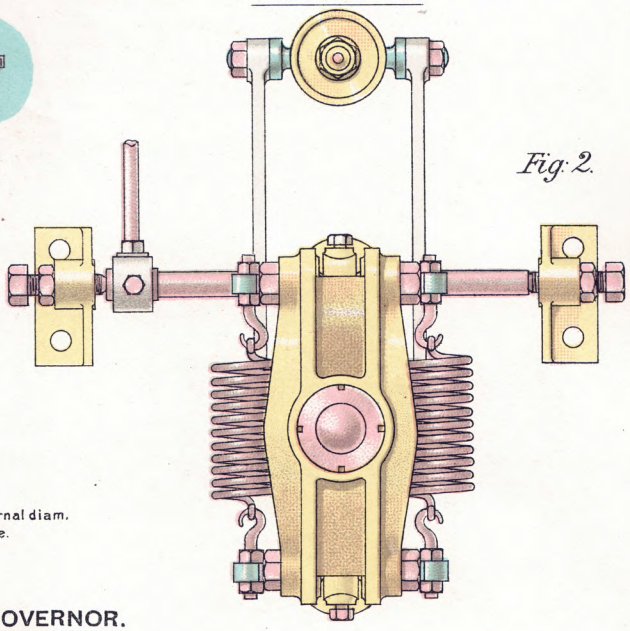


Fig: 2.

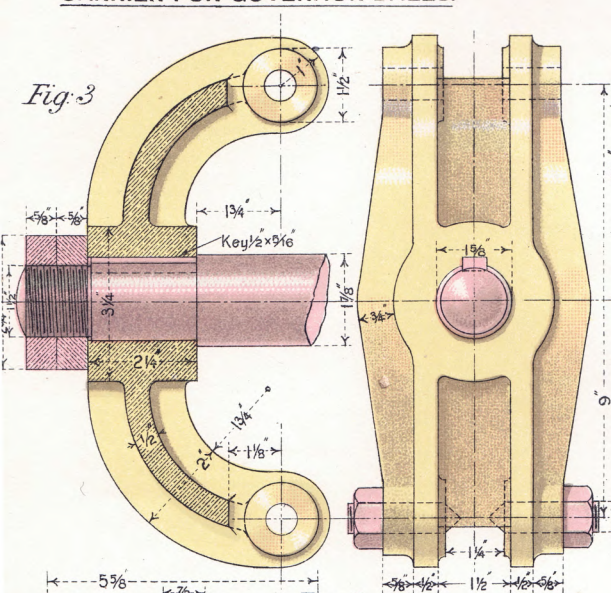


DETAILS OF GOVERNOR.

Scale 3"=1 Foot.

CARRIER FOR GOVERNOR BALLS.

Fig: 3



SLEEVE

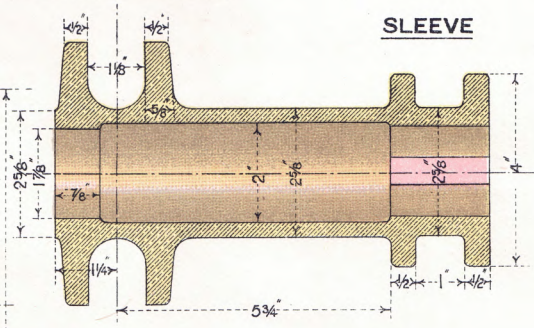
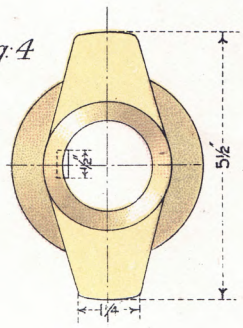


Fig: 4



ROCKING LEVERS.

Fig: 7.

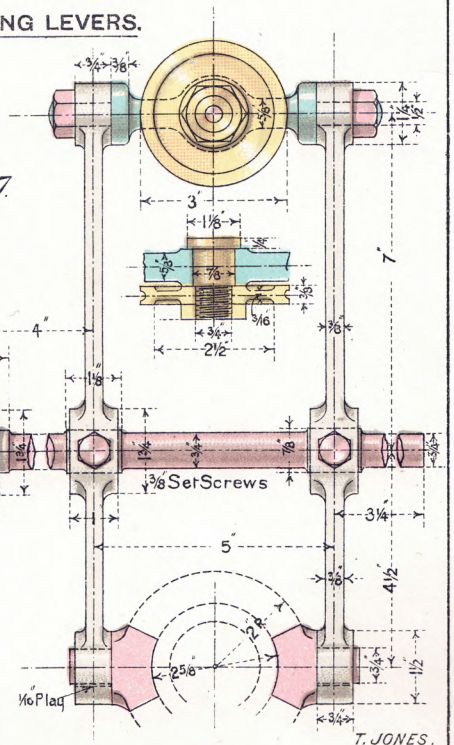
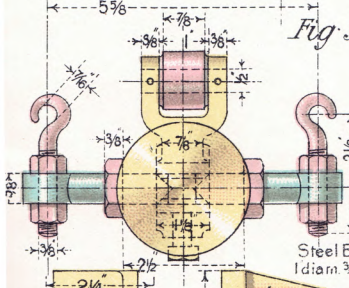
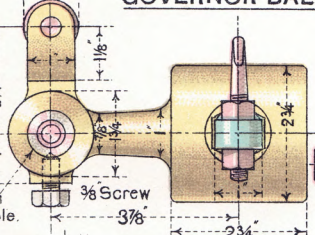
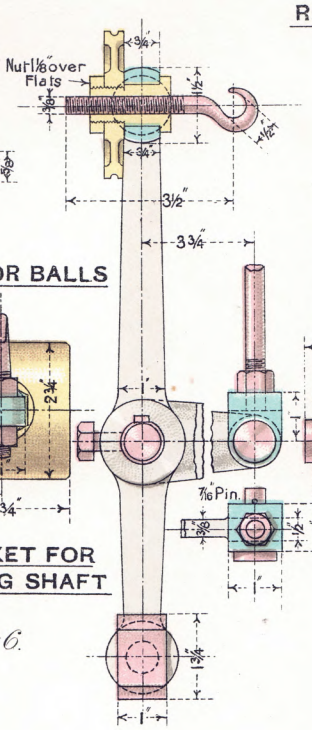


Fig: 5.



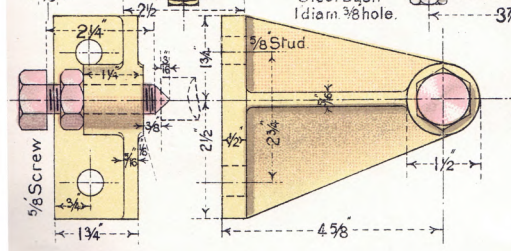
GOVERNOR BALLS





BRACKET FOR ROCKING SHAFT

Fig: 6.



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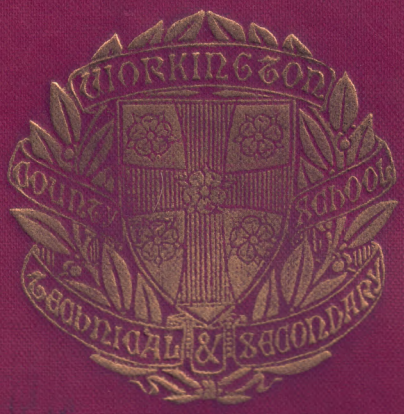
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